The Impact of Basel III Regulation in a DSGE Model for Norway with Credit Market Imperfections

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Summary

In November 2010 the G-20 Seoul summit endorsed the new capital regulatory framework proposed by the Basel Committee on Banking Supervision (BCBS). This is the second major revision of the initial Basel Capital Accord from 1988. The proposed regulatory framework is announced to be implemented into national legislation by EU and European Economic Area (EEA) members by 2013 as a new set of directives (CRD IV). Several studies conducted by, among others, Macroeconomic Assessment Group of the FSB and the BCBS, the Institute of International Finance, OECD Economics Department and Norges Bank have evaluated the likely impact on the banking sector and the overall economy in general. There seems to be consensus on the direction of the impact in all the studies mentioned, but not on the degree. Economic output is mainly assumed to be affected by an increase in bank lending spreads as banks pass a rise in bank funding costs, arising from higher capital requirements, to their customers. The studies conducted by Macroeconomic Assessment Group and OECD Economics Department estimate that banks will increase their lending spreads on average by about 15 basis points in order to meet the capital requirements effective in 2015.

The aim of this thesis is to investigate the medium term economic impact of the new capital regulatory standards (the Basel III reform) for Norway using a standard semi-structural dynamic stochastic general equilibrium (DSGE) model with credit market imperfections. The following questions are answered: (i) what are the major expected effects of higher minimum capital requirement on the Norwegian banking sector and on medium-term economic performance? (ii) How is the inclusion of a proposed countercyclical capital buffer, when made dependent on either the credit-to-GDP or the real credit growth as common reference point, affecting the model economy and in particular GDP and credit growth?

The main findings of this study are the following: (1) each percentage point increase in the capital adequacy ratio translates into a 0.50 per cent loss in the level of steady state output. The long-run effect of a persistent shock to the capital adequacy ratio equation propagates through the banking sector block in the model to the real sector, affecting output by as much as -0.55 percentage points at its peak before shifting output to a new steady-state level between 0.50 and 0.55 percentage below its initial level. (2) The application of a countercyclical capital buffer based on a prudential rule that increases the capital requirement when the credit-to-GDP ratio rises seems capable of moderating credit growth in the model, but it increases the output volatility. More up to date findings in the literature suggest that the

use of credit-to-GDP gap as a common reference point could be flawed and at worst increase the inherent pro-cyclicality of bank capital regulation. Reproducing the same methods to investigate this issue for Norway seems to confirm this undesirable property. Findings from the estimated model suggest that the use of a buffer, with credit-to-GDP gap as a reference point alters the sign of the correlation between output growth and bank capital, producing a strong negative correlation of -0.61. In order to circumvent this issue, real credit growth is employed as an alternative indicator. The use of real credit growth, both as a leading indicator of systemic risk and as a common reference point, seems to moderate credit growth in a sizeable way and output growth to some extent. Finally, the model seems to generate a slightly higher correlation between output and bank capital, confirming that the use of real credit growth, next to having some desirable properties, also seems able to produce results in the model economy that are closely in line with the main objectives of Basel III and its mandate.

Preface

During a semester spent at the University of Essex in England in spring 2011, I came across a paper written by Grégory de Walque and Olivier Pierrard in The Economic Journal, 2010, with the title "Financial (In)Stability, Supervision and Liquidity Injections: A Dynamic General Equilibrium Approach." I was immediately fascinated by and drawn to their attempt to incorporate financial intermediation into a Dynamic Stochastic General Equilibrium (DSGE) framework. Highly inspired by issues in contemporary economics of banking and banking regulation, I embarked on a quest to study regulatory impact using a DSGE model. I was, not far down the road, increasingly frustrated by the huge literature within the field of DSGE modeling and the lack of experience in dealing with large scale models. However, after my first meeting with my supervisor Paolo Gelain at Norges Bank, I was slightly reassured. Through my continued correspondence and collaboration with him I was properly introduced to the world of DSGE modeling and programming. I therefore wish to extend my sincere and deepest gratitude to him for his support and guidance throughout the research. This thesis would not have been possible without his patience and the many hours spent in finding a suitable model. The equation in section 6 of this paper, outlining a rule for the countercyclical capital buffer, is all attributable to him.

My sincere appreciation and special thanks is extended to Nina Larsson Midthjell at the Economics Department for providing me with a list of corrections and for giving me constructive feedback. This feedback was crucial and has helped me improve the thesis to a great extent.

Special thanks to Norges Bank for providing me with data and resources to conduct my research.

My sincere appreciation is extended to Professor Jon Vislie and Professor Asbjørn Rødseth at the Economics Department and to Ragna Alstadheim and Bent Vale both researchers at Norges Bank for both introducing and inspiring me to delve deeper into the banking literature through the lectures given in the course Economics of Banking (ECON4335) at the University of Oslo.

Special thanks to the staff at the Department in Economics at University of Oslo, for introducing and deepening my knowledge in the fascinating field of economics.

I will also like to extend my deepest gratitude to my family, and especially to my beloved fiancée, Maral, for her unending love and support, not to mention understanding,

during my progress of writing this thesis and in all my endeavors. Without their encouragement I will not have fully pursued my goals.

I will also like to thank my friend and fellow student of economics, Christopher Okazaki Hansen, for reading my thesis and for providing me with constructive feedback.

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1 Introduction

In December 2009, the Basel Committee on Banking Supervision (BCBS) issued a consultative document outlining proposals for strengthening regulations of banks' capital and liquidity following the lessons learned from the US financial turmoil ("Strengthening the resilience of the banking sector", Bank for International Settlements, December 2009). The proposed set of regulations, also known as Basel III, is the second major revision of the initial Basel Accord of 1988 which is a set of standards for harmonizing solvency regulations for internationally active banks of the G-10 countries. The proposal was endorsed in late November 2010 by the G20 Seoul Summit and is likely to be implemented by the EU and the European Economic Area (EEA) members by 2013 as a new set of directives (CRD IV).[1]

Several studies have been conducted in order to quantify the likely impact and consequence the new set of regulations will have on bank's lending spreads, as well as the macroeconomic impact on aggregate credit and output. In August 2010, the Basel Committee and the Financial Stability Board (FSB) issued two reports assessing the impact of Basel III. These followed the publication of estimates of this impact by other bodies, including one by the Institute of International Finance (IIF), an industry body of international banks.

One of the two official reports of the Macroeconomic Assessment Group of the FSB and the BCBS (referred to as the MAG report in what follows) is concerned with the impact during the transition period when the new requirements for capital and liquidity are being phased in and focuses exclusively on the costs of introducing the new requirements.[2] The other report of a working group of the BCBS analyzes the long-term economic impact of Basel III.[3] "Long-term" is defined by the assumption that banks have completed the transition to the new regulations on capital and liquidity. This report assesses the economic benefit as well as the costs of regulations.

The MAG report's estimates of the deviations of output from baseline in the eighteenth quarter after the implementation of increased capital requirements are modest. For a one per cent increase in the capital ratio using a transition period of four years, the median

[1] "CRD IV" (Capital Requirements Directive), is based on the new framework (Basel III) proposed by BCBS and is expected to be implemented by January 2013. In Norway the CRD IV will apply for all Banks and financial institutions.
[2] "Assessing the macroeconomic impact of the transition to stronger capital and liquidity requirements", Interim Report, Bank for International Settlements, August 2010.
[3] "An Assessment of the long-term economic impact of stronger capital and liquidity requirements," Basel Committee on Banking Supervision, August 2010.

estimate is a decrease of output of about 0.15 per cent. The result shows that an increase in the capital ratio by two per cent translates into a decrease of output of 0.30 per cent.

The report on the assessment of the long-term economic impact of stronger capital and liquidity requirements presents a range of estimates of costs and benefits according to different levels of the ratio of capital to risk-weighted assets (RWA) and according to whether or not the capital rules are accompanied by additional requirements for liquidity. A one per cent increase in the capital ratio is associated with a 0.09 per cent annual reduction of GDP without additional liquidity requirements, and with a 0.17 per cent reduction of GDP if coupled with additional liquidity requirements.

For the IIF report, the cumulative difference during the period 2011-2015 between GDP in the scenario incorporating regulatory change and the baseline scenario is 3.1 per cent. This figure corresponds to annual average difference of 0.6 per cent.[4]

A study published by Slovik and Cournède (2011) at the OECD Economics Department argues that "to meet the Basel III requirements effective as of 2015 banks would increase their lending spreads on average by approximately 15 basis points. To meet the Basel III requirements effective as of 2019 banks would increase their lending spreads on average by approximately 50 basis points". In the three main OECD economies, a one percentage point increase in the ratio of bank capital to risk weighted assets would result in an average impact on GDP level of −0.20 per cent, five years after the implementation, which translates into a −0.04 percentage point impact on annual GDP growth.

A further impact study conducted by researchers at Norges Bank with the title "Macroeconomic impact of higher capital requirements for banks," analyzes the likely impact on the Norwegian economy using an estimated structural vector auto regression (VAR) model.[5] The paper studies the impact of a permanent increase of one percentage point in the core minimum capital requirement on the baseline credit and output gap levels. Since there are some uncertainties as to when the banks will choose to raise their capital adequacy ratio the baseline scenario used range from 2, 4 and 8 quarters. Predictably the results show that the effects are strongest for the two quarters phase in period, peaking after 2-3years with credit-supply contracting by 3 per cent and the GDP growth deviating from baseline trend by 1.25 per cent, the effect wears out after three years. The mean reversion back to pre-shock levels in

[4] IIF, "The Net Cumulative Economic Impact of Banking Sector Regulation: Some New Perspectives", October 2010.

[5] "Makroøkonomiske virkninger av høyere kapitalkrav for bankene" Staff Memo 14/2011, Norges Bank.

their model is largely due to monetary policy easing (Jacobsen et al, 2011).

The principal objective of this paper is using an estimated open economy dynamic stochastic general equilibrium (DSGE) model for Norway with credit market imperfections to (i) evaluate the major expected effects of Basel III's proposal to increase minimum capital requirement on the Norwegian banking sector and the subsequent macroeconomic impact on medium-term economic performance, and (ii) to evaluate the impact of a new feature proposed by Basel III, i.e. the countercyclical capital buffer, on economic fluctuations. It is worth emphasizing that the focus of the paper is on the costs of the new regulations, as the methodology used is not intended to capture the benefits. Once the model structure is readily set up, the parameters of the model are estimated by means of Bayesian estimation to incorporate stylized facts along with judgments and the information from the data.

In general this thesis makes two innovative contributions. First, the paper analyzes the Basel III regulation through the lenses of a semi-structural model for Norway. The core of the model is a "reduced form" New Keynesian DSGE model while the banking sector is specified using an econometric approach for reasons explained later in the text. As far as I know, this is the first attempt of this kind. Previous studies for Norway are based on a pure econometric model, as in Jacobsen et al. (2011). Second, the introduction of a countercyclical capital buffer by Basel III has not previously been analyzed in a macroeconomic model, and as such, the conceptualizing and modeling of a countercyclical capital buffer for a structural model economy of Norway is, to my knowledge, first explored and attempted in this paper.

The main results of this study are the following: (1) each percentage point increase in the capital adequacy ratio translates into a 0.50 per cent loss in the level of steady state output. The long-run effect of a persistent shock to the capital adequacy ratio equation propagates through the banking sector block in the model to the real sector, affecting output by as much as -0.55 percentage points at its peak before shifting output to a new steady-state level in the range of 0.50 and 0.55 percentage below its initial level. (2) A prudential rule that increases the capital requirement when the credit-to-output gap rises seems capable of moderating credit growth. However, as argued by Repullo and Saurina (2010), the use of credit-to-GDP deviation from steady state as a "common reference point" for taking buffer decisions may end up exacerbating the inherent pro-cyclicality of risk-sensitive bank capital due to a discernible negative correlation between credit-to-GDP gap and output growth. This issue can be tackled, as they argue further, by the use of real credit growth, which is positively correlated with output growth, as a common reference point instead. Using real credit growth, I was, in addition to moderating excessive credit growth, also able to reduce output volatility in a sizeable way able. Moreover the results confirm, by generating a positive correlation of 0.22 between output growth and bank capital, that the use of real credit growth is better suited for mitigating pro-cyclicality in the model.

The paper is organized as follows. Section 2 reviews briefly the experience from the financial crisis which started in 2008 followed by a summary of the Basel Accords and the latest proposals for Basel III. Section 3 develops a baseline DSGE model for Norway that incorporates financial intermediation. Section 4 will provide an overview of the statistical methodology, data series, and validation of model fit, prior distributions and calibrated parameters. Section 5 discusses the different effects on and responses of the endogenous variables and shows the impulse responses from two different shocks; a monetary policy shock and a shock originating from banks' capital adequacy ratios. Section 6 considers the use of a countercyclical capital buffer as a tool for mitigating pro-cyclicality and the build-up of systemic-wide-risk, followed by a discussion on the use of credit-to-GDP gap as a common reference point for making decisions on the build-up and release of the buffer. Lastly, Section 7 provides some conclusions.

2 Regulatory Reform and Capital Requirements

In the summer of 2007 the US economy was severally hit by the sudden burst of the housing bubble. The resulting decline in real estate prices and the subsequent increase in banks lending spreads led many households to default on their mortgages, forcing many large and reputable banks to write down substantial portions of their loan portfolios. The drop in asset prices eroded the capital positions of the financial institutions, who, in turn, responded by tightening lending standards and increasing margins further. Both effects tightened the volume of lending and pushed prices further down, exacerbating the *"liquidity spiral".* (Brunnermeier, 2009).

According to Rogoff and Reinhart (2009) severe financial crises rarely occur in isolation. In addition to triggering a likely recession, they often amplify "the reversal of fortunes" i.e. lower output growth leads to more defaults on bank loans, which in turn force a pullback in other bank lending, exacerbating the ongoing economic slowdown and repayment problems and so on.[6] This interconnected link between the banking sector and the real economy was described by Fisher (1933), with his understanding of a debt-deflation process playing a central role in the propagation of cyclical fluctuations and by the workings of Bernanke (1983) and more recently in a formalized model on the "financial accelerator" by Bernanke et al. (1999).

Clearly the magnitude of this amplification mechanism is determined by the macroeconomic environment. Banks with ever increasing proportions of non-performing loans and loan losses face a depletion of bank capital and a reduction in their internal buffers. The US financial turmoil revealed that certain Tier 1 capital instruments – classified as core capital – were unable to absorb losses. Consequently new macro-prudential regulations were called for, and in December 2010 new rules on capital and liquidity were negotiated and finally agreed upon through the Basel Committee on Banking Supervision. The agreement, known as "Basel III", has tightened its definitions of regulatory capital. Tier 1 capital will now be comprised predominantly of common shares and retained earnings. The introduction of these new regulatory requirements will have a large effect on the world's financial systems

[6] It is also reasonable to assume that a leakage of bad performance of bank loan portfolios could trigger a fundamental bank run i.e. when depositors learn bad news about their bank, they could fear bankruptcy and respond by withdrawing their deposits (Freixas and Rochet, 2009: 230).

and economies. The main aim is to make the national financial systems, as well as the global financial system, more robust and safer (BCBS, 2009a).

2.1 The Basel Capital Accords and Basel III Proposals

The failure of the small German bank (Herstatt) on June 26, 1974, sent shockwaves through the global financial system due to poor coordination among national regulators. The G-10 countries responded to this “Herstatt debacle” by forming a standing committee under the affiliation of the Bank for International Settlements (BIS) called the Basel Committee on Banking Supervision (BCBS). The Committee is composed of representatives from central banks and regulatory authorities. In 1988, the Committee introduced a capital measurement system referred to as the Basel Capital Accord also known as Basel I. The Basel accords are not formal treaties and the conclusions of BCBS are not always fully implemented in detail into national law and regulation by its member states. In any event, the accord has led to greater uniformity of capital requirements globally since it formulates supervisory standards and guidelines and recommends statements of best practice. Basel I considered only credit risk. It required international banks from the G-10 countries to hold a minimum total capital equal to 8 percent of risk-adjusted assets, with at least half of this met by tier 1 capital (equity capital and disclosed reserves). Tier 2 Capital could include, among other instruments, hybrid debt capital instruments (BCBS, 2009).

The Basel II revisions made changes to the risk-weighted asset calculations and placed greater emphasis on proactive supervision and market discipline. The revisions are commonly referred to as the three pillars of Basel II. The four major changes where: (1) the introduction of more detailed risk-categories, (2) greater reliance on external ratings from the major credit rating agencies (3) use of internal risk rating models, and (4) a different method was introduced to calculate the risk of assets that were held in trading accounts. Thus a “Value at Risk” (VaR) approach was used. The recent financial crisis exposed a number of areas of weakness in the Basel II rules. This led to a call for a new framework for bank capital and liquidity.

Basel III extends the three pillars of Basel II and requires banks to hold 4.5 per cent of common equity and 6 per cent of Tier 1 capital of risk-weighted assets (RWA). [7] In addition,

[7] Main features are described in Caruana (2010).

to the core-capital requirements, Basel III also introduces capital buffers, (i) a mandatory capital conservation buffer of 2.5 per cent and (ii) a discretionary countercyclical capital buffer, which allows national regulators to require up to another 2.5 per cent of capital during periods of high credit growth. [8] In addition, Basel III introduces a minimum 3 per cent leverage ratio and two required liquidity ratios. The liquidity coverage ratio requires a bank to hold sufficient high-quality liquid assets to cover its total net cash flows over 30 days; the Net Stable Funding ratio requires the available amount of stable funding to exceed the required amount of stable funding over a one-year period of extended stress (BCBS, 2009a). The additional liquidity regulation is also conceived to have a major effect. This effect has been studied using a separate model and is also accounted for in the MAG report. In the remainder of the paper the focus will lay solely on capital regulation, thus, the effect of liquidity regulation is ignored.

While it is agreeable that having too little capital in the system may leave it crisis prone and in need of regular bailouts, forcing banks to have higher capital cushions, on the other hand, could have adverse effects (e.g. higher borrowing costs and lower economic growth). [9] It is therefore conceivable that Basel III could inadvertently be ill-suited by several (possibly concurring) factors and the framework set in motion can as a result involve costs that exceed their expected benefits. Since the new set of regulations can affect economic performance and give rise to conflicting effects through multiple channels, the impact is closely studied using a stylized DSGE model for the Norwegian economy. The descriptions as well as the use of the model are the topic of next section.

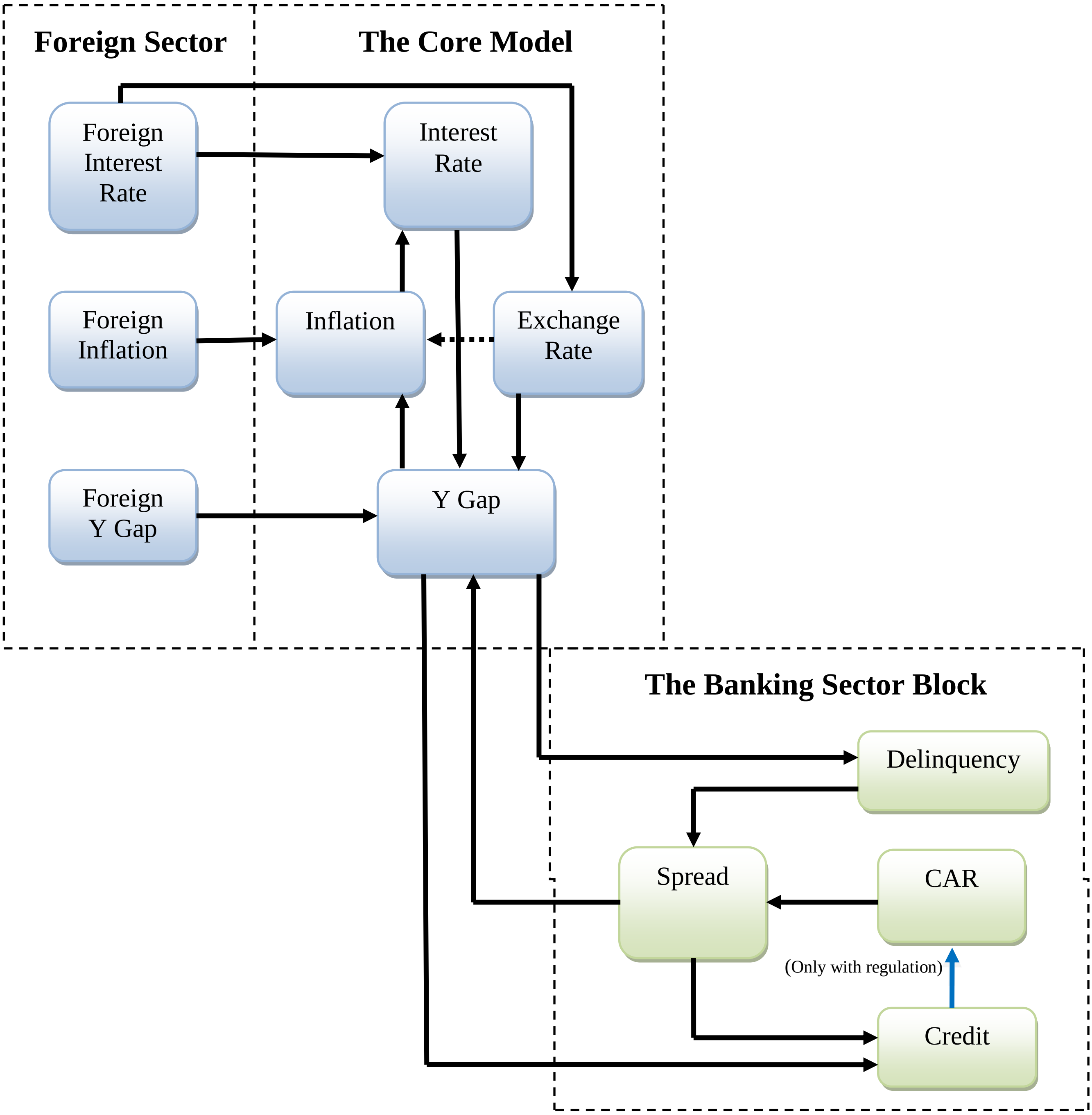
[8] Proposed Basel III norms ask for ratios as: 7- 9.5% (4.5% + 2.5% (conservation buffer) + 0-2.5% (seasonal buffer)) for common equity and 8.5% to 11% for Tier 1 capital and 10.5% to 13% for total capital (BCBS, 2009a).

[9] See Santos (2001b) for a review of the justifications for bank capital regulation in contemporary banking theory.

3 The Model

The baseline framework used in this paper is a semi-structural small new Keynesian open economy model with imperfect competition. The model is composed of three sectors as shown in figure 1. (1) A core part describing the relationship between main macroeconomic aggregates for the Norwegian economy. (2) An open economy sector, captured using three variables describing the Euro Area (EA) (Assumed to represent the “rest of the world”), namely EA inflation, EA nominal interest rate and EA output gap. All the EA variables are treated as exogenous to the core model. (3) A macroeconometric banking sector block is used to incorporate financial intermediation into the model. The structure of the core and the open economy sector of the model are very similar in terms of equations to those in Sidaoui and Ramos-Francis (2008). The choice of the framework provided by their paper is due to a convenient set-up by the author of the standard new Keynesian open economy model that, in addition to capturing the main macroeconomic features of the Norwegian economy well, proves suitable for the incorporation of a macroeconometric banking sector block. The use of a macroeconometric banking block, which is heavily influenced by Peñaloza (2011), is a symptom of the lack of a simple, but still fully, micro-founded model for banking behavior. The framework used by Peñaloza (2011) provides an alternative perspective that includes costs of default and positive lending spreads; a feature that is essential to account for credit market imperfections and to study the potential amplifying role of financial factors on macroeconomic developments. In fact, the presence of lending spreads as endogenous variables in the model is an essential feature that allows me to conduct my analysis and to evaluate the expected reaction of the banking sector. A crucial assumption made is that the banks pass their increased costs to their customers through higher spreads. This in turns explains the negative impact on output of higher minimum capital requirements. Further, the model is in a reduced form. This means that although the structure of the equations are in line with those derived in the context of a fully fledge New Keynesian DSGE model (preserving some specific features and theoretical explanations at the basis of their final version, like for instance the rational expectations assumption and the presences of habit formation in consumption, and price indexations among others), combinations of structural parameters that would appear in the equations as the results of the solution of the agents’ maximization problems will be treated as unique parameters. This is a shortcut justified by the fact that this simplifies the estimation procedure (reducing the number of parameters to be estimated) and by the fact that the aim is to get an estimated model which captures the dynamics of the Norwegian macroeconomic variables rather than a point estimate of the structural parameters.[10] This strategy will also be helpful in selecting prior means for the parameters.

Figure.1: The Model[11]



[10] This is done in Brubakk (2006).

[11] This figure depicts the main building blocks and resource flows inside the stylized Norwegian DSGE model.

3.1 The Core of the Model

In this section I will present the core model of the Norwegian economy. This is a similar model to the one used by Peñaloza (2011) with some minor differences that will be further explained. The core of the model is as mentioned a semi-structural small open economy new Keynesian DSGE model and is structured in the following manner:

The core model is structured as follows:

1. An IS curve for the output gap.
2. An Augmented Phillips curve for price inflation.
3. An equation for real-exchange rate dynamics.
4. Imported inflation (CPI).
5. A monetary policy rule.

The IS-equation outlined below links the evolution of aggregate demand (output gap) to the real-interest rate, foreign output gap and the real exchange rate.

$$x_t = b_1 x_{t-1} + b_2 E_t[x_{t+1}] - b_3 r_t + b_4 x_t^{EA} + b_5 q_t + u_t^D \qquad (1)$$

where x_t is the output gap, defined as the current level of output relative to its steady-state level (its mean in the data), $r_t \equiv i_t - E_t[\pi_{t+1}]$ is the real interest rate (with $E_t[\pi_{t+1}]$ being the expected gross CPI inflation rate and i_t the short term nominal interest rate), q_t is the real exchange rate, x_t^{EA} is the Euro Area output gap.[12] The disturbance term u_t^D follows an AR(1) process $u_t^D = \rho_{u^D} u_{t-1}^D + u_t^{u^D}$, where the autocorrelation coefficient ρ_{u^D} is between 0 and 1 in absolute value, with i.i.d. errors $u_t^{u^D} \sim N(0, \sigma_{u^D}^2)$.[13] The parameters b_1, b_2, b_3, b_4, and b_5 will be restricted to be positive in the estimation process and the signs to capture the relationships among varaibles are set into the equations appropriately.[14] The formulation of equation (1), also known as the Euler equation, reflects the forward-looking nature of the

[12] The real-interest rate (i.e. purchasing power repaid over purchasing power lent) is the standard Fisher identity.

[13] The specification of the exogenous shock processes as following an independent AR(1) process is very much in line with other studies found in the literature for estimated DSGE models (Schorfheide, 2010)

[14] This is true for all the parameters in all equations.

agents as well as the presence of habit in their consumption pattern. As Norway is a small open economy, the real exchange rate q_t can affect the level of economic activity through the prices of imports and exports, while Euro area output gap x_t^{EA} is an important determinant of export demand. The demand disturbance u_t^D can arise from a taste shock to the preferences of the representative household.

Now, turning to the supply side of the model, an equation for domestic inflation is presented. The equation bears a resemblance to the so called new Keynesian Phillips curve. The difference is due to open economy features captured by the incorporation of exchange rate and foreign inflation and is defined as the following:

$$\pi_t^D = a_1\pi_{t-1}^D + a_2E_t[\pi_{t+1}^D] + a_3x_t + a_4[\Delta e_t + \pi_t^{EA}] + v_t^{\pi^D} \tag{2}$$

Where π_t^D denote domestic inflation and x_t is the output gap. The difference operator Δe_t in the equation is used to capture changes in the nominal exchange rate, and π_t^{EA} takes into account movements in the Euro area inflation.[15] The disturbance term v_t^D represents a cost push shock. The disturbance term follows an AR(1) process $v_t^{\pi^D} = \rho_v v_{t-1}^{\pi^D} + u_t^v$, where $\rho_{u^D} \in (0,1)$ and $u_t^v \sim N(0, \sigma_{u^v}^2)$. Parameter a_1 characterizes the endogenous persistence of inflation, while a_2 allows forward-looking behavior by firms and households to affect the inflation process, and a_3 captures the short-run tradeoff between inflation and the output gap. The parameter a_4 represents the pass-through of the nominal exchange rate and EA inflation to domestic inflation. Equation (2) implies that the inflation process is forward-looking, in which current inflation is a function of expected future inflation.[16] It equally follows the indexation to the past value of inflation (or wages). The main determinant driving the inflation process is the output gap. This is in line with the more detailed specification often found in a fully fledge DSGE model where the real marginal cost is derived to be the correct driving variable for the inflation process and prices are set as mark-ups over marginal costs subject to limited probability of re-setting prices in each period.[17] The two formulations

[15] Summaries the long sentence below.
[16] Inflation can be shown to be a function of the present discounted value of current and future real marginal costs (Walsh, 2010: 336).
[17] The model of price stickiness is taken from Calvo (1983). He assumed that firms adjust their prices infrequently, and that opportunities to adjust arrive as an exogenous Poisson process. Individual firms produce differentiated products, they all have the same production technology and face demand curves with constant and equal demand elasticity.

equivalently capture the positive relationship between real economic activity and inflation.

Further, since the term for change in the nominal exchange rate is included in equation (2) I will without further due define and explain the mechanism behind this variable. The change in the nominal exchange rate is given by:

$$\Delta e_t = \Delta q_t + \pi_t^D - \pi_t^f$$

Where Δe_t is the change in the nominal exchange rate, Δq_t is change in the real-exchange rate, while π_t^D is the domestic inflation as described by equation (2) and π_t^f represent imported inflation as defined in equation (3). According to the equation depicted above the percentage depreciation of the nominal exchange rate is equal to the real exchange rate depreciation plus the inflation differential between the domestic and the foreign economy. This implies that a decrease in the relative price of foreign goods gives rise to a nominal exchange rate appreciation.

The third component making up the structure of the core model is the real-exchange rate. Equation (3) below is the Uncovered Interest Rate Parity condition (UIRP), where r_t^{EA} captures the EA real-interest rate and r_t the domestic real-interest rate. It implies that the home country real interest rate will exceed the foreign real rate if the home country is expected to experience a real depreciation. Real exchange rate depreciation reduces home aggregate supply by raising the price of imported goods and by raising consumer prices relative to producer prices.

$$q_t = c_1 q_{t-1} + c_2\{E_t[q_{t+1}] + (r_t^{EA} - r_t)\} + \omega_t^q \quad (3)$$

Under flexible exchange rates a fall in the domestic rate of inflation boosts aggregate demand through three effects. First, it makes domestically produced goods less expensive relative to foreign goods and shifts demand away from foreign output and toward home output. Second, it induces the central bank to reduce the interest rate, thereby stimulating investment and consumption. However, the somewhat reduced policy rate has a dampening effect on the real interest rate, so the initial effect is at best short lived. Third, the lower interest rate causes a depreciation which gives a further stimulus to net exports. The disturbance term ω_t^q is a shock to the real-exchange rate that follows an AR(1) process $\omega_t^q = \rho_\omega \omega_{t-1}^q + u_t^\omega$, where

$\rho_\omega \in (0,1)$ and $u_t^{\omega} \sim N(0, \sigma^2_{u^\omega})$. The change in the real-exchange rate is defined as the following $\Delta q_t = q_t - q_{t-1}$.

The fourth component of the core model is the equation for imported inflation. As in Adolfsen et al. (2007a) the households in this open economy model consume a basket consisting of both domestically produced goods and imported goods, assuming that these products are supplied by domestic and importing firms, respectively. A separate equation is included to capture imported inflation and is given by:

$$\pi_t^f = \rho_f \pi_{t-1}^f + u_t^f \tag{4}$$

Where π_t^f represents imported inflation and u_t^f denote the associated disturbance term. The u_t^f is a cost push shock to inflation that follows an AR(1) process $u_t^f = \rho_{u^f} u_{t-1}^f + u_t^{u^f}$,where $\rho_{u^f} \in (0,1)$ and $u_t^{u^f} \sim N(0, \sigma^2_{u^{u^f}})$. In particular, exporting and importing firms in the model operate by selling differentiated consumption goods to foreign and domestic markets subject to the local currency price stickiness and indexation to past inflation

Finally, to sum up the inflation dynamics in the model CPI inflation is assumed to be a weighted average of domestic inflation and imported inflation (Adolfsen). The dynamics of core inflation are described by the New-Keynesian Phillips curve provided by equation (2) above, while imported inflation is given by equation (4).

$$\pi_t = w_1 \pi_t^D + w_2 \pi_t^f + \mathcal{E}_t^\pi$$

Where π_t represents overall inflation composed of domestic inflation (π_t^D) and foreign inflation (π_t^f). The parameters w_1 and w_2 are different weights ascribed to the two different sources for inflation.[18] The disturbance term $\mathcal{E}_t^\pi$ is a measurement error term that follows an AR(1) process $\mathcal{E}_t^\pi = \rho_{\mathcal{E}^\pi} \mathcal{E}_{t-1}^\pi + u_t^{\mathcal{E}^\pi}$, where $\rho_{\mathcal{E}^\pi} \in (0,1)$ and $u_t^{\mathcal{E}^\pi} \sim N(0, \sigma^2_{u^{\mathcal{E}^\pi}})$. This error term is included to circumvent the issue of the so called errors-in-variables problem.[19]

Lastly, an equation for the monetary policy rule is presented. The behavior of the

[18] To see a DSGE based derivation of equation (4), see Adolfsen et al. (2007). The weights w_1 and w_2 are functions of the structural parameters like for instance, among others, the share of the importing consumption and for this reason they do not necessarily sum up to one.
[19] The errors-in-variables problem is concerned with the implication of using incorrectly measured variables.

central bank is approximated with an instrument rule, more specifically a modified Taylor rule. Following Smets and Wouters (2003a), the policy maker is assumed to adjust the short term nominal interest rate in response to deviations of CPI inflation and output deviations from steady-state. This adjustment process is defined as the following:

$$i_t = (1\text{-}d_3)[(1 + d_1)\pi_t + d_2 x_t] + d_3 i_{t-1} + \varepsilon_t^i \tag{5}$$

The parameter d_1 measures the response of the Central bank to inflation, while d_2 describes its reaction to output gap fluctuations. Since d_1 is bigger than 0 in the estimation, the expression $(1 + d_1)$ is included in order to respect the Taylor principle. The lagged interest rate features interest rate smoothing, as is evident from practice. [20] The monetary policy shock is described by the disturbance term $\mathcal{E}_t^i$ that follows an AR(1) process $\mathcal{E}_t^i = \rho_{\mathcal{E}^i}\mathcal{E}_{t-1}^i + u_t^{\mathcal{E}^i}$, where $\rho_{\mathcal{E}^i} \in (0,1)$ and $u_t^{\mathcal{E}^i} \sim N(0, \sigma^2_{u^{\mathcal{E}^i}})$. Although the monetary policy shock might be perceived by some authors as white noise, recent estimations of DSGE model as in Smets and Wouters (2007) show that an autoregressive structure for this shock is not an unreasonable assumption. The estimated auto correlated coefficient is found to be positive, but reasonably low. My findings are in line with this study.

3.2 The foreign sector of the model

The euro area part of the model is subject to its own set of structural shocks that are designed to reproduce the monetary policy conducted by the European Central Bank, and to act as a foreign market for Norwegian exports and imports. Specification outlined for the EA variables are for the sake of convenience exogenously given and follows an AR (1) process. This allows for a more flexible representation of the reduced form dynamics of these variables.

As a consequence the Euro area inflation will be described by the following equation:

[20] A modified Taylor rule which includes the lagged interest rate on the right-hand side comes close to being optimal, according to Rotemberg and Woodford (1999).

$$\pi_t^{EA} = \rho_{\pi^{EA}} \pi_{t-1}^{EA} + \mathcal{E}_t^{\pi^{EA}} \tag{6}$$

Where π_t^{EA} is the euro area inflation and $\rho_{\pi^{EA}}$ is the autoregressive coefficient restricted between 0 and 1. Finally, $\mathcal{E}_t^{\pi^{EA}}$ is a disturbance term that is itself a function of an AR(1) process $\mathcal{E}_t^{\pi^{EA}} = \rho_{\mathcal{E}^{\pi^{EA}}} \mathcal{E}_{t-1}^{\pi^{EA}} + u_t^1$, where $\rho_{\mathcal{E}^{\pi^{EA}}} \in (0,1)$ and the error term is $u_t^1 \sim N(0, \sigma_{u^1}^2)$.

Secondly, Euro area output-gap is also described as an AR(1) process and is given by:

$$x_t^{EA} = \rho_{x^{EA}} x_{t-1}^{EA} + \mathcal{E}_t^{x^{EA}} \tag{7}$$

Where x_t^{EA} is the euro area inflation. $\mathcal{E}_t^{x^{EA}}$ is a disturbance term that follows an AR(1) process $\mathcal{E}_t^{x^{EA}} = \rho_{\mathcal{E}^{x^{EA}}} \mathcal{E}_{t-1}^{x^{EA}} + u_t^2$, where $\rho_{\mathcal{E}^{x^{EA}}} \in (0,1)$ and $u_t^2 \sim N(0, \sigma_{u^2}^2)$.

And lastly, the Euro area real-interest rate is described as following an independent AR(1) process and is outlined below as:

AR (1) process

$$r_t^{EA} = \rho_{r^{EA}} r_{t-1}^{EA} + \mathcal{E}_t^{r^{EA}} \tag{8}$$

Where r_t^{EA} is the euro area real-interest rate. $\mathcal{E}_t^{r^{EA}}$ is a disturbance term that follows an AR(1) process $\mathcal{E}_t^{r^{EA}} = \rho_{\mathcal{E}^{r^{EA}}} \mathcal{E}_{t-1}^{r^{EA}} + u_t^3$, where $\rho_{\mathcal{E}^{r^{EA}}} \in (0,1)$ and $u_t^3 \sim N(0, \sigma_{u^3}^2)$. The nominal interest rate is given by the fisher equation, $i_t^{EA} = r_t^{EA} + E[\pi_{t+1}^{EA}]$, and is set by the European Central Bank for the euro area. Where i_t^{EA} is the nominal interest rate, r_t^{EA} is the real interest rate for the euro area and $E[\pi_{t+1}^{EA}]$ represents the expected inflation rate for the euro area one period ahead.

3.3 The Banking Sector

In this section I adopt a macroeconometric approach as in Peñaloza (2011) in order to incorporate financial intermediation into the core model for the reasons explained above. Despite this specification of the banking sector block, many of the features of the banking model implied by, among others, Gertler and Kyotaki (2010) are implicitly assumed to be inherent. One such inherent property is credit market imperfection and the subsequent “financial accelerator” it gives rise to, as argued by Bernanke et al. (1999). Motivated by a stylized “balance sheet” for Norwegian banks, banking activity is predominantly modeled as the production of deposit and loan services and the banking technology is assumed to reflect the cost of managing a volume of equity and deposits (both retail and wholesale), and a volume of loans; making loans to non-financial corporations and issuing credit to mortgages.[21] Applying this framework allows us to study the effect of an increase in the minimum capital requirement, i.e. reducing the leverage, on banks’ lending spreads as well as the volume of lending, assuming that the increase in funding cost is passed on to borrowers. Lending spreads are within this framework dependent on banks’ delinquency indexes and capital. The rationale behind the use of delinquency indexes is, as pointed out by Peñaloza (2011), “an assumption that banks increase their lending spreads when they face higher delinquency indexes and when they increase their equity ratio so as to keep their return on equity (ROE) roughly constant.” Delinquency indexes are specified as a function of their lagged values and the output gap. The relationship between delinquency indexes and the output gap allows for a feedback from the core-model to the banking sector block. The aggregate credit in circulation is modeled so as to react positively to changes in the output gap and negatively to lending spreads.

The banking sector block consists of a set of equations that are linked to each other and to the core model. The building blocks of the banking sector are as following:

9. A modified IS equation that incorporates lending spreads.
10. Equations for lending spreads by sector.
11. Equations for delinquency indexes by sector.
12. Equation for a credit by sector.
13. A “rule” for the capital adequacy ratio.

A Modified IS Equation is included in order to capture spill-over effects from the banking sector to the real economy, the IS-equation (9) below have been modified to include lending spreads ($spread_t$). The mechanism is, as argued by Peñaloza (2011), “in line with some of the work done in Macroeconomic-Assessment-Group (2010a).” The modified IS-equation is defined as the following:

[21] Banks raise funds in a national financial market. Within the national financial market, there is a retail market, where banks obtain deposits from households; and a wholesale market, where banks borrows and lend amongst one and another (Gertler & Kyotaki (2010)).

$$x_t = b_1 x_{t-1} + b_2 E_t[x_{t+1}] - b_3 r_t + b_4 x_t^{EA} + b_5\, q_t - b_6\, spread_t + \mathcal{E}_{x,t} \tag{9}$$

Where the components in the equation are defined exactly in the same way as for equation (1) with the exception of the term $spread_t$ which denotes the aggregate lending spread. The construction of the lending spreads is explained more thoroughly below. The idea behind the use is that lending spreads can affect the output gap by affecting aggregate demand (An increase in the overall lending spread will induce households and non-financial corporations to cut back on spending), thus, an increase (decrease) in lending spreads will have a negative (positive) effect on the output gap.

The second component of the banking block is the equation for aggregate sectorial lending spreads. The regulatory impact on bank lending spreads is estimated based on accounting identities applied to aggregated banking sector lending spreads. The equations below utilize sector specific delinquency indexes combined with a banking system equity ratio (capital/risk-weighted assets) to capture sectorial lending spreads.

$$spread_t^j = \gamma_1^j spread_{t-1}^j + \gamma_2^j delin_t^j + +\gamma_3^j\, CAR_t + \mathcal{E}_{spread^j,t} \tag{10}$$

The lending spread is defined for both non-financial corporations and for mortgages so that j= {corp, mort}, and delin_t^j is the delinquency index in sector j and CAR_t is the capital adequacy ratio of the banking sector. The disturbance term $\mathcal{E}_{spread^j,t}$ follows an AR(1) process $\mathcal{E}_t^{spread^j} = \rho_{\mathcal{E}^{spread^j}} \mathcal{E}_{t-1}^{spread^j} + u_t^{\mathcal{E}^{spread^j}}$, where $\rho_{\mathcal{E}^{spread^j}} \in (0,1)$ and $u_t^3 \sim N(0, \sigma^2_{u^{\mathcal{E}^{spread^j}}})$.

Next, we turn to the third component, namely the delinquency indexes. The idea behind this construct is that delinquency indexes are low (high) when economic activity is high (low), reflecting an inverse relationship –as evident by empirical findings- between the debt-servicing capacity of borrowers (i.e. non-financial corporations and households) and the output gap. This relationship is defined as the following:

$$delin_t^j = \varphi_1^j delin_{t-1}^j - \varphi_3^j\, x_t + \mathcal{E}_{delin^j,t} \tag{11}$$

Where $delin_t^j$ are the sectorial specific delinquency indexes, j= {corp, mort}. The parameter φ_3^j with a negative sign in front, capture the notion that delinquency indexes follow developments in the output gap. The disturbance term $\mathcal{E}_{delin^j,t}$ follows an independent AR(1) process $\mathcal{E}_t^{delin^j} = \rho_{\mathcal{E}^{delin^j}} \mathcal{E}_{t-1}^{delin^j} + u_t^{\mathcal{E}^{delin^j}}$ where $\rho_{\mathcal{E}^{delin^j}} \in (0,1)$ and the error term is $u_t^{\mathcal{E}^{delin^j}} \sim N(0, \sigma^2_{u^{\mathcal{E}^{delin^j}}})$.

Next in line is the construction of the sectorial demand for credit. The following equation specifies demand for credit of each type (i.e. credit volume by sector). The central tenet behind the use is that aggregate credit in circulation is driven by demand. Aggregate demand for credit, or in our case sectorial demand, is high and increasing when the economy is booming (i.e. during an expansion) and low and decreasing during a recession reflected by an ever increasing output gap. A second component affecting demand for credit is lending spreads. As lending spreads increase so does the cost of credit and the demand goes down. In the opposite case when lending spreads are low and falling, credit becomes cheap, or less costly, and the demand for it goes up. Keeping in line with this intuition credit allocations is given by:[22]

$$cr_t^j = \mu_1^j cr_{t-1}^j - \mu_2^j spread_t^j + \mu_3^j\, x_t + \mathcal{E}_{cr^j,t} \tag{12}$$

Where cr_t^j is the demand for credit, j= {corp, mort}.The disturbance term $u_t^{\mathcal{E}^{cr^j}}$ follows an independent AR(1) process $\mathcal{E}_t^{cr^j} = \rho_{\mathcal{E}^{cr^j}} \mathcal{E}_{t-1}^{cr^j} + u_t^{\mathcal{E}^{cr^j}}$ where $\rho_{\mathcal{E}^{cr^j}} \in (0,1)$ and the error term is $u_t^{\mathcal{E}^{cr^j}} \sim N(0, \sigma^2_{u^{\mathcal{E}^{cr^j}}})$.

Before moving into a discussion about the last component of the banking block some identities and definitions are defined and presented.

Aggregate delinquency is defined as the following:

$$delin_t \equiv \delta_{corp} delin_t^{corp} + (1 - \delta_{corp}) delin_t^{mort} + \mathcal{E}_t^{delin}$$

[22] As noted by Peñaloza (2011) the structure of the model so far places sectorial credit gaps as residual variables. It is only when they enter the reaction functions of the regulatory authorities (CAR rule) that they affect lending spreads, and consequently output. This feature is made clear in figure.1 above.

Where $delin_t$ denotes aggregate delinquency, while $delin_t^j$ represents sector specific delinquency indexes. Each of them are given a different weight denoted by δ_{corp}. The disturbance term $\mathcal{E}_t^{delin}$ is a measurement error term that follows an AR(1) process $\mathcal{E}_t^{delin} = \rho_{\mathcal{E}^{delin}} \mathcal{E}_{t-1}^{delin} + u_t^{\mathcal{E}^{delin}}$ where $\rho_{\mathcal{E}^{delin}} \in (0,1)$ and $u_t^{\mathcal{E}^{delin}} \sim N(0, \sigma^2_{u^{\mathcal{E}^{delin}}})$.

Aggregate lending spreads is given by:

$$spread_t \equiv \tau_{corp} spread_t^{corp} + (1 - \tau_{corp}) spread_t^{mort} + \mathcal{E}_t^{spread}$$

Where $spread_t$ denote aggregate lending spreads, while $spread_t^j$ represents sector specific lending spreads. Each of them are given a different weight denoted by τ_{corp} and $(1 - \tau_{corp})$. The disturbance term $\mathcal{E}_t^{spread}$ follows an AR(1) process $\mathcal{E}_t^{spread} = \rho_{\mathcal{E}^{spread}} \mathcal{E}_{t-1}^{spread} + u_t^{\mathcal{E}^{spread}}$ where $\rho_{\mathcal{E}^{spread}} \in (0,1)$ and $u_t^{\mathcal{E}^{spread}} \sim N(0, \sigma^2_{u^{\mathcal{E}^{spread}}})$.

And lastly, aggregate credit is defined as the following:

$$cr_t \equiv \tau_{corp} cr_t^{corp} + (1 - \tau_{corp}) cr_t^{mort} + \mathcal{E}_t^{cr^{tot}}$$

Where cr_t denote aggregate credit, while $credit_t^j$ represents the share of credit accrued to the two different sectors. Each of them are given a different weight denoted by τ_{corp} and $(1 - \tau_{corp})$. The disturbance term $\mathcal{E}_t^{cr^{tot}}$ follows an AR(1) process $\mathcal{E}_t^{cr^{tot}} = \rho_{\mathcal{E}^{cr^{tot}}} \mathcal{E}_{t-1}^{cr^{tot}} + u_t^{\mathcal{E}^{cr^{tot}}}$ where $\rho_{\mathcal{E}^{cr^{tot}}} \in (0,1)$ and $u_t^{\mathcal{E}^{cr^{tot}}} \sim N(0, \sigma^2_{u^{\mathcal{E}^{cr^{tot}}}})$.

Finally, a credit-to-GDP gap is defined. This is a variable that will be used to a great extent in section 6. As for now a simple formulation is in place and is defined as the following:

$$m_t = cr_t - x_t$$

In the following, two different equations impacting banks' equity ratios are presented. These equations reproduce the two dimensions to capital's role as argued by Disyatat

(2010).[23] First out is an equation for the baseline capital adequacy ratio. This specification attempts to capture in the simplest possible way the evolution of commercial banks' (at an aggregate level) capital adequacy ratios and is defined as:

$$CAR_t = \Theta_1 CAR_{t-1} + \alpha_1 CAR_t^R + \mathcal{E}_{CAR,t} \tag{13}$$

Where CAR_t denote the baseline capital adequacy ratio, while CAR_t^R is the externally imposed regulatory requirement. In equation (35) α_1 is a switching parameter that is equal to 1 if there is regulation in place and equal to 0 otherwise. Given that the regulation has not been in place in the past, data would not have been informative to estimate this parameter. This is the reason why I don't estimate it and I allow it to be a binary variable. Lastly, an error term is included. This error term $\mathcal{E}_{CAR,t}$ follows an AR(1) process $\mathcal{E}_t^{CAR} = \rho_{\mathcal{E}^{CAR}} \mathcal{E}_{t-1}^{CAR} + u_t^{\mathcal{E}^{CAR}}$ where $\rho_{\mathcal{E}^{CAR}} \in (0,1)$ and $u_t^{\mathcal{E}^{CAR}} \sim N(0, \sigma^2_{u^{\mathcal{E}^{CAR}}})$.

The capital adequacy ratio rule is on the other hand specified only in terms of the countercyclical capital buffer. A detailed specification is provided in section 6, along with the use of two different indicators for making buffer decisions.

$$CAR_t^R = z_t \tag{14}$$

3.4 Measurement Equations

In this section I explain how I bring the model to the data. I follow two different strategies. First, I will use a series of measurement equations and secondly I will use some identities. With respect to the former I present the following measurement equations. I will use growth rates of some variables as observables in the estimation process and given that some other observables do not appear as endogenous variables in the model I need to provide a series of measurement equations and definitions to create the link between the statistical definitions of

[23] "From the perspective of banks' creditors, the amount of capital signifies the extent to which any losses will be cushioned which, in turn, influences the rate at which they are willing to lend to banks, and second, from the banks' perspective, the presence of regulatory capital requirements acts like a hard constraint on asset expansion" (Disyatat, 2010).

those variables and their theoretical definitions inside the model.

Starting with growth rates I define the output gap growth rate as:

$$x_{GROWTH,t} \equiv x_t - x_{t-1}$$

The measurement used for GDP growth for Norway is the quarter-on-quarter growth and is defined as the following. Where $x_{GROWTH,t}$ denote the quarter-on-quarter GDP growth for Norway, while x_t and x_{t-1} captures the current and previous GDP rates, respectively.

The measurement employed for the growth of credit to non-financial corporations' is the quarter-on-quarter data for credit growth and is defined as:

$$cr_{GROWTH,t}^{corp} \equiv cr_t^{corp} - cr_{t-1}^{corp}$$

Where $cr_{GROWTH,t}^{corp}$ denotes the quarter-on-quarter credit growth, while cr_t^{corp} and cr_{t-1}^{corp} captures the current and previous share of total credit accrued to non-financial corporations.

The measurement used for the growth of credit to mortgages is the same as the one for non-financial corporations and is defined as following:

$$cr_{GROWTH,t}^{mort} \equiv cr_t^{mort} - cr_{t-1}^{mort}$$

Where $cr_{GROWTH,t}^{mort}$ denotes the quarter-on-quarter credit growth, while cr_t^{mort} and cr_{t-1}^{mort} captures the current and previous share of total credit accrued to the mortgage sector.

Overall credit growth is used as an observable variable and is measured in the same manner as for the sectorial credit growth. The credit growth for Norway is given by:

$$cr_{GROWTH,t} \equiv cr_t - cr_{t-1} + \mathcal{E}_t^{cr}$$

Where $cr_{GROWTH,t}$ denote the quarter-on-quarter credit growth for Norway, while cr_t and cr_{t-1} captures the current and previous credit rates, respectively. $\mathcal{E}_t^{cr}$ is a measurement error term that follows an AR(1) process $\mathcal{E}_t^{cr} = \rho_{\mathcal{E}^{cr}} \mathcal{E}_{t-1}^{cr} + u_t^{\mathcal{E}^{cr}}$, where $\rho_{\mathcal{E}^{cr}} \in (0,1)$ and the error term is $u_t^{\mathcal{E}^{cr}} \sim N(0, \sigma_{u^{\mathcal{E}^{cr}}}^2)$.

The measurement used for the Euro area GDP growth rate is the same as the one used for GDP growth for Norway and is given by:

$$x^{EA}_{GROWTH,t} \equiv x^{EA}_{t} - x^{EA}_{t-1}$$

Where $x^{EA}_{GROWTH,t}$ denote the quarter-on-quarter GDP growth, while x^{EA}_{t} and x^{EA}_{t-1} captures the current and previous GDP rates for the Euro area, respectively.

Then turning to the remaining observables I will in the following define and explain the real-interest rates used for non-financial corporations and households as well as the lending spreads for each sector.

In line with the rational expectations hypothesis, agents, in our case non-financial corporations, make decisions based on the real-interest rate (i.e. taking into account expected inflation). It was therefore important to define these variables. The real-interest rate for non-financial corporations' is given by:

$$r^{corp}_{t} = i^{corp}_{t} - E[\pi_{t+1}]$$

Where r^{corp}_{t} represent the real-interest rate for the sector as a whole, and i^{corp}_{t} is the nominal interest rate demanded. Lastly, $E[\pi_{t+1}]$ captures the expected CPI inflation one period ahead given the available information about the state variables at time t.

The real-interest rate for mortgages is included for the same reason as above and is defined as the following:

$$r^{mort}_{t} = i^{mort}_{t} - E[\pi_{t+1}]$$

Where r^{mort}_{t} represent the real-interest rate for mortgage, and i^{mort}_{t} is the nominal interest rate demanded, while $E[\pi_{t+1}]$ captures the expected CPI inflation one period ahead.

Lending spread for non-financial corporations are the difference between the real-interest rates demanded for borrowing credit and the risk-free real-interest rate. The lending spread is denoted as the following:

$$spread^{corp}_{t} \equiv r^{corp}_{t} - r_{t}$$

Where $spread^{corp}_{t}$ is the lending spread, and r^{corp}_{t} is the real-interest rate for the sector as a whole, while r_t is the general real-interest rate.

Lending spread for mortgages is defined in the same manner as for non-financial corporations and is given by:

$$spread_t^{mort} \equiv r_t^{mort} - r_t$$

Where $spread_t^{mort}$ is the lending spread, and r_t^{mort} is the real-interest rate for mortgages, while r_t is the risk-free real-interest rate.

4 Data and Priors

In order to estimate the stochastic properties of the exogenous driving forces I employ Bayesian methods, using quarterly Norwegian data over the sample period 1992:1-2010:4. I used 17 observables in the estimation. These observables are per-capita real quarter on quarter growth for GDP, domestic credit to the general public, domestic credit to households, and domestic credit to non-financial enterprises. Three inflation rates are used, namely the CPI, domestic and imported inflation, and three different interest rates are used, namely the interest rate on credit to households, the interest rate on credit to firms, and the nominal 3-month money market rate. The real exchange rate for Norway over this period is included. In addition, two different delinquency indexes are used for non-financial corporations and household mortgages, respectively.[24] Numbers from the Norwegian banks' equity ratios is used. And lastly, three Euro Area variables are utilized, i.e. EA GDP growth, EA inflation and the 3 month EA nominal interest rate. All variables are expressed and percentage deviation from their mean.

As for the prior distributions I adopted the following commonly used selection strategy for their shape. For the standard deviation of the shocks I adopted an inverse gamma distribution for its positive domain. For those parameters restricted between 0 and 1 I selected either a beta distribution or a uniform distribution. The remaining parameters are assumed to be normally distributed. The mean of the prior distributions are selected fairly easily for some very standard parameters (e.g. as' and bs'), while I draw from Peñaloza's estimations for the less known parameters (e.g. μs' and γs') (Peñaloza, 2011).

I provide an evaluation of the open economy DSGE model's empirical properties to validate the model fit; these results are provided in figures 3-5 below. The model fit shows that the stylized DSGE model seems to underestimate slightly the standard deviation and the autocorrelation of output when the model is simulated a large number of times. Nevertheless, the overall impression remains that the model fits the data reasonably well.

[24] Delinquency indexes used by Peñaloza (2011) is the adjusted delinquency indexes, which are the sum of overdue loans and loans written-off in the prior twelve months divided by total loans plus loans written-off in the last twelve months. I follow Peñaloza in the construction of the delinquency indexes for Norway. The data for constructing the delinquency indexes used in this paper was kindly provided by the Norges Bank.

4.1 Bayesian Estimation

Bayesian estimation is easy to conceptualize, but is technically very intensive. It is beyond the scope of this paper to provide a detailed description of the procedure and as such I will in the following outline the basic concepts and leave the more in-depth technically aspects of the procedure to be found in, among others, An and Schorfheide (2007) and Canova (2007). Nevertheless, given the scientific nature of this work it is also necessary to report a fair minimum amount of technical details for which I draw from Gelain and Kulikov (2009).

The Bayesian technique allows the researcher first to use prior information from earlier studies at both macro and micro level in a formal way, and then to supplement or confront the model with data. [25] Priors can be regarded as weights on the likelihood function that gives certain areas of the parameter subspace a greater weight. The Bayesian technique starts out with Bayes' formula assuming that both data and parameters are random variables given by:[26]

$$f(\theta \mid Y) = \frac{f(\theta)L(\theta;Y)}{f(Y)} \propto f(\theta)L(\theta;Y) \qquad (15)$$

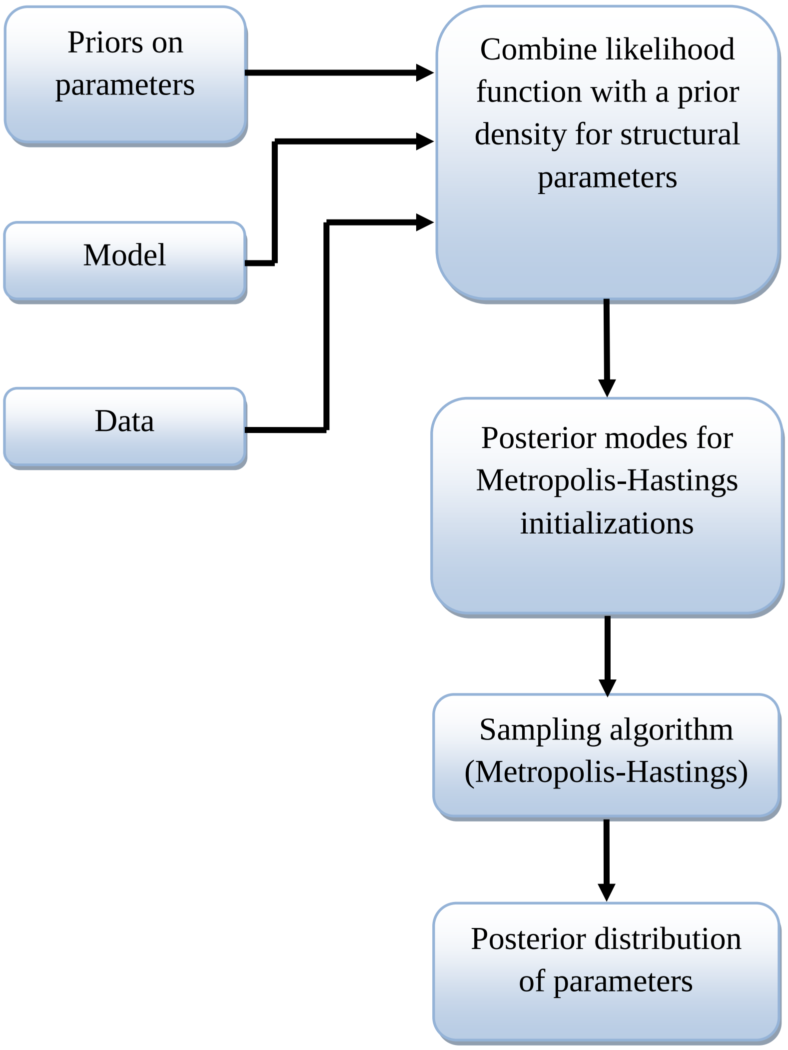
Where Y is a set of observable data over a sample period, M is the model and θ is a set of the model parameters. According to Gelain and Kulikov (2009) "Bayesian statistics can be viewed as a learning process," where observed data collected in Y is used to learn about the posterior distribution $f(\theta \mid Y)$of a k-dimensional vector of model parameters $\boldsymbol{\theta}$, given the likelihood function $L(\theta;Y)$ and the prior distribution $f(\theta)$. The combination of the prior and the likelihood function is maximized and scaled by marginal data density to yield the posterior mode $f(\theta \mid Y)$. The Kalman filter is needed because the endogenous variables of the model involve certain quantities for which no observable counterparts can be found in macro-economic statistics. With this posterior mode, I employ computationally intensive Monte-Carlo method (Sampling algorithm based on Metropolis-Hastings) to generate θ draws and produce posterior distribution of parameters. Bayesian estimation process in this paper is programmed in Dynare on Matlab. Figure 2 provides a general overview of the steps involved in the construction of the likelihood function for a typical DSGE model. Independent prior

[25] See the application of Bayesian estimation on a comprehensive DSGE model in Gelain and Kulikov (2009).

[26] Where$f(Y) = \int_{R^k} f(\theta)L(\theta;Y)\,d\theta$ can be treated as a normalizing constant for the purpose of posterior inference.

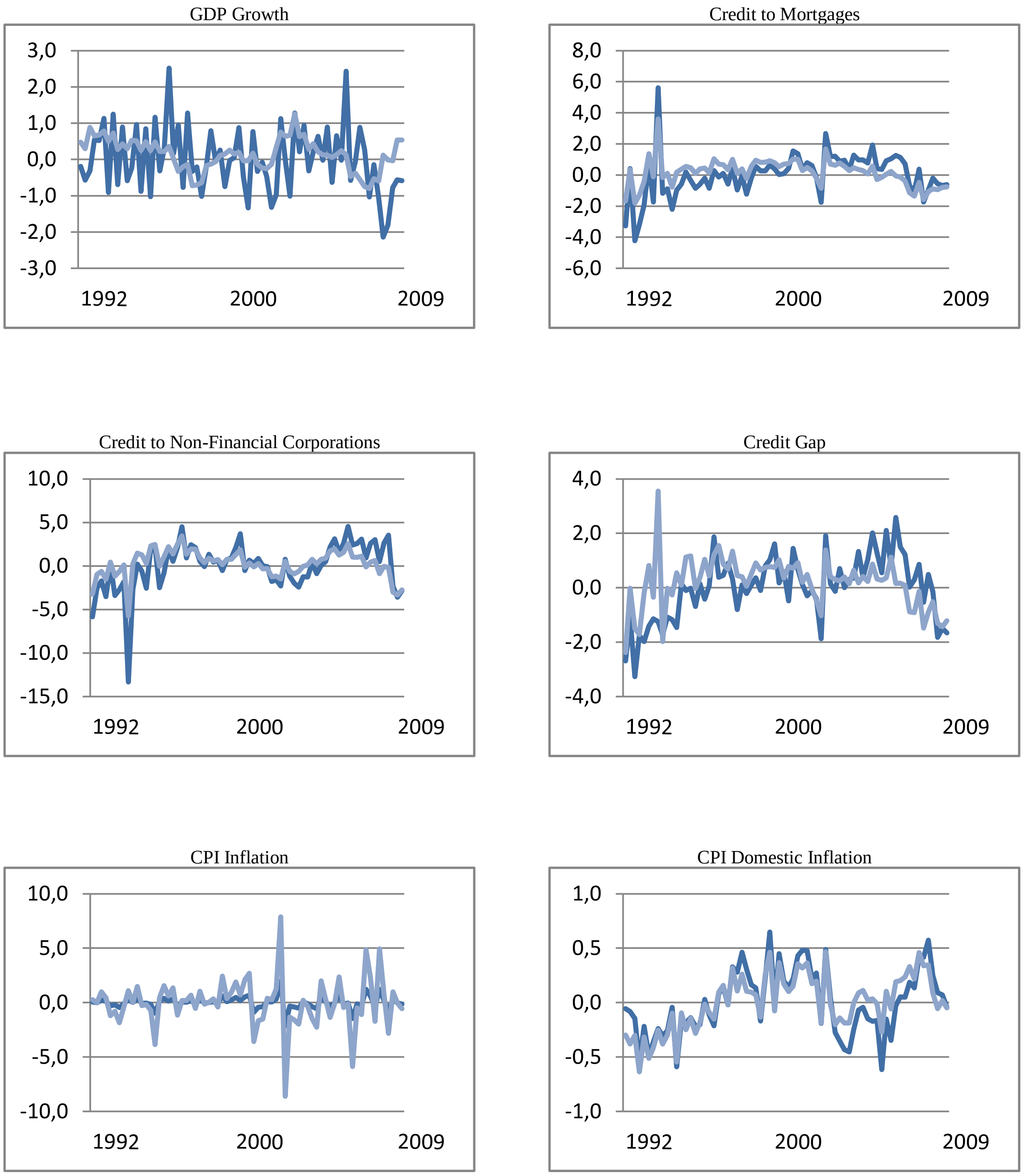
densities are formulated for 75 parameters of the model, namely, 22 autoregressive coefficients, 18 main structural parameters for the core model, 17 banking block related parameters and 18 parameters of the data-generating processes for the disturbances. Table 1-4 in the appendix reports the prior means, the posterior means and the 5 per cent and 95 per cent bounds for each of these parameters. The statistical estimates of the main structural parameters are largely in line with previous studies for Norway.[27]

Figure 2: Bayesian estimation process



[27] See Brubakk et al. (2006).

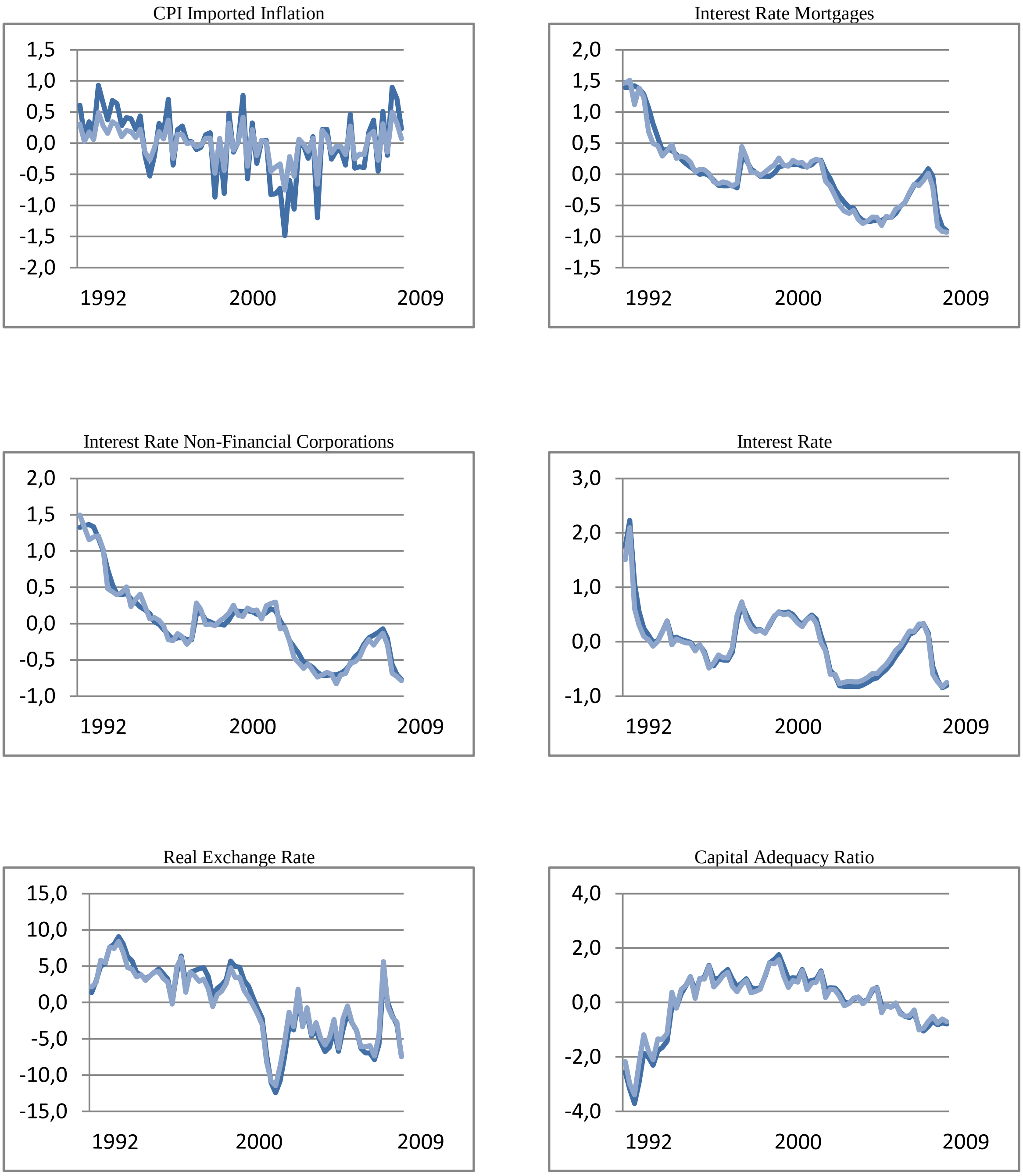
Figure 3: Fitted and Actual Values[28]



Source: Norges Bank

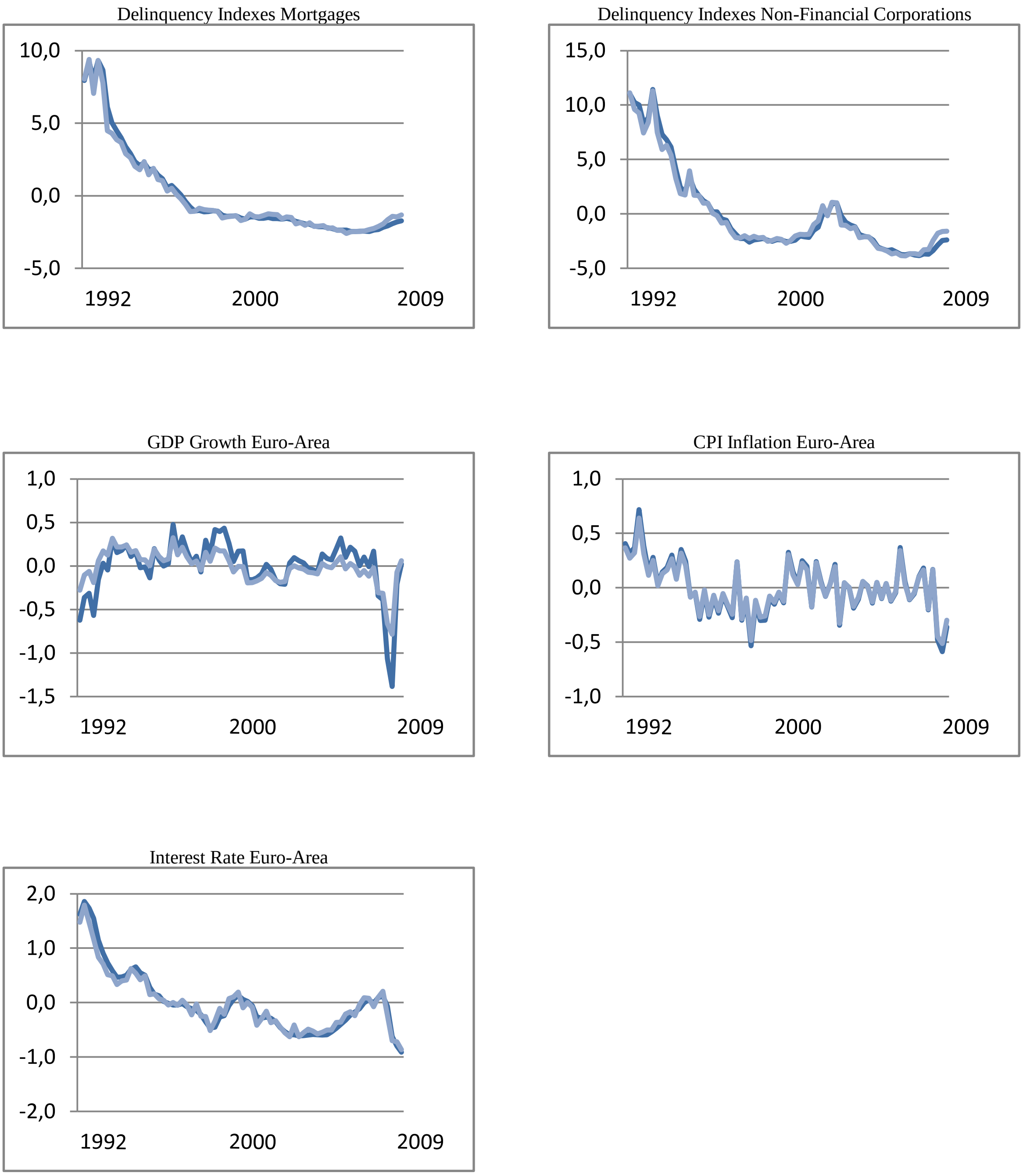
[28] Actual data (blue line) and corresponding one-step ahead linear Kalman filter forecasts evaluated at the posterior mode (light-blue line).

Figure 4: Fitted and Actual Values



Source: Norges Bank

Figure 5: Fitted and Actual Values



Source: Norges Bank

5 Model Response to Structural Shocks

In this section, I study the model properties of the estimated Norwegian DSGE model by conducting an impulse response analysis. Impulse-response functions show how an initial shock propagates through the model economy, and how the main macroeconomic aggregates respond over time to different shocks. All impulse-response functions are based on the mode of the posterior distributions of all parameters. I will first present the monetary policy shock to validate the model fit in order to be confident in the evaluation of shocks such as the CAR shock. The final simulation exercise examines responses to a permanent structural shock arising from a permanent one per cent increase in the capital adequacy ratio.

5.1 Impulse-response functions

Figure 6 show the dynamic responses of the impulse functions to a one standard deviation in the monetary policy shock and the capital adequacy ratio shock, respectively. I will treat the shock as a one-time disturbance which hits the model economy in a single period. In this way I am able to highlight how the economy's reaction to the shock will generate persistent deviations from trend even if the shock itself is purely temporary. Figure 6 show the impulse-response functions for some of the endogenous variables in the model generated by a temporary increase in our monetary policy shock variable, while Figure 7 show the impulse-response functions responding to an exogenous tightening of regulatory policy for selected variables. See appendix for an overview of the responses of all the variables used in the model. The solid line represents the estimated response, with the dashed lines capturing the corresponding 95 per cent confidence interval. The scale on the horizontal axis measures the number of quarters after the initial shock

I first evaluate the monetary policy shock shown in figures 6. I study the effect of a one standard deviation shock to the Taylor rule on the Norwegian economy. This is equivalent to evaluating an increase of 25 basis points in the key policy rate. The effect on output, depicted in the top left graph of figure 6, is negative. The graph displays a characteristic hump-shaped pattern, reaching a trough after four quarters at 0.55 percentage points below its original level before slowly reverting back to its baseline level. This effect seems somewhat large for Norway given previous empirical evidence, but it is still in line with it.[29] The extra effect comes from the accelerator effect due to the presence of credit market imperfections in the model. The increase in the spread caused by the recession puts an extra burden on firms and households debts, forcing them to reduce investments and consumption respectively, which in turn further depresses the economy. In an estimated version with no financial friction the impact is 0.4 per cent. Inflation also reacts negatively because of the recession induced increase in interest rate. Again the 0.015 per cent drop is in line with previous empirical evidence for Norway. Real exchange rate is also falling by about 1 per cent.

The results above allow me to be confident about the dynamic properties of the model and in judging the effects of a transitory shock to the banks' capital adequacy ratio, which are displayed in figure 7. I report a one standard deviation shock for the sake of comparison with other studies, among others, Jacobsen et al. (2011). I will discuss here a shock of the magnitude of 1 per cent rather than of 0.4 per cent as in the figure.[30] The shock is propagated via the banking sector in the model. Banks in the model respond to the temporary increase in their equity ratio by predominantly increasing lending spreads. The effect of a 1 per cent increase of banks' capital requirement on output is negative, with a drop of 0.5 per cent at its peak reached after four quarters. This is somewhat in line with the findings in Jacobsen et al. (2011) when they employ the alternative model called the Small Macro Model.[31] Credit seems to follow a somehow similar pattern responding by a small initial drop from baseline by -0.3 percentage point, followed by a continuing movement away from the original level in the subsequent quarters, reaching a trough in the sixth quarter at -1.54 percentage point before gradually progressing back to its initial steady-state. The deviation of output from its initial level reflects a drop in economic activity due to an increased debt burden that distorts resources away from demand and productive use, and a slowdown in credit attributable to both a reduction in the debt-servicing capacity of both non-financial corporations and households and from higher delinquency indexes stemming from non-performing loans and loan losses.

[29] The impulse responses for the main macroeconomic aggregates seems to be fairly similar to the once presented in an article describing the "Norwegian Economy Model" (NEMO) used by Norges Bank (Brubakk et al. (2006)).
[30] "To obtain the 1 per cent effect I simply multiply all impulse response functions by 2.5"
[31] Used for stress testing analysis within Norges Bank according to the appendix in Jacobsen et al. (2011).

Figure 6: Impulse Response Functions Results[32] (Monetary policy shock)

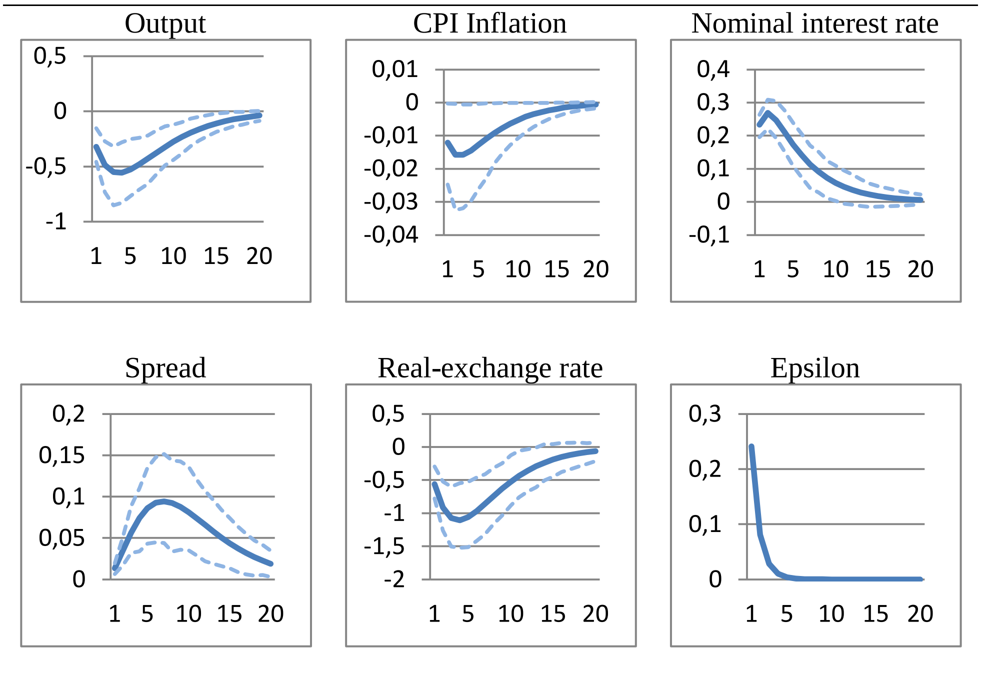
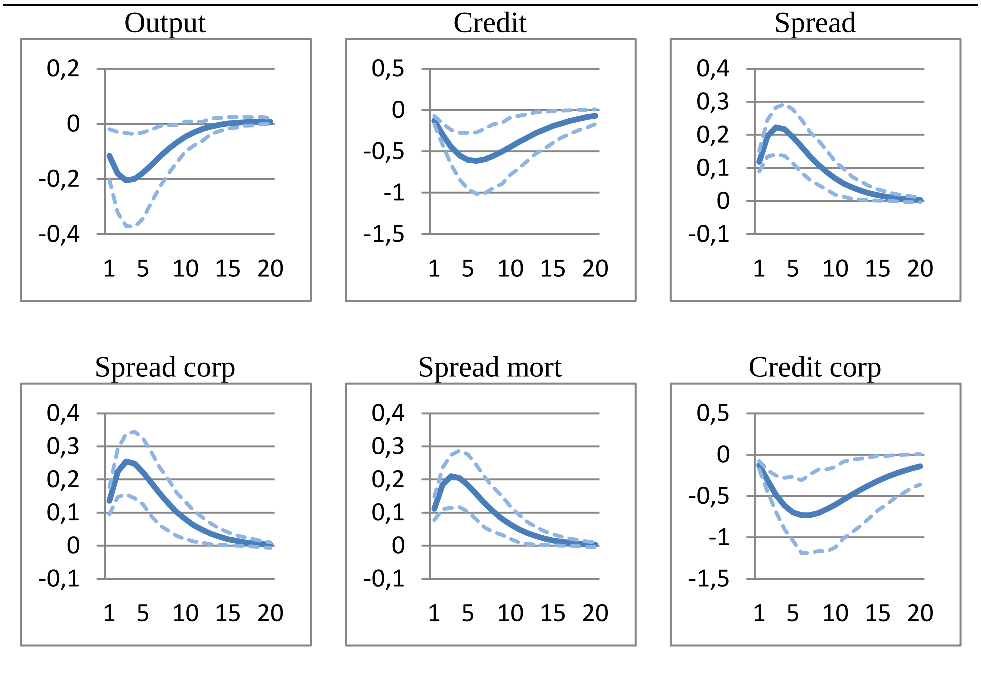


Figure 7: Impulse Response Functions Results (CAR shock)[33]



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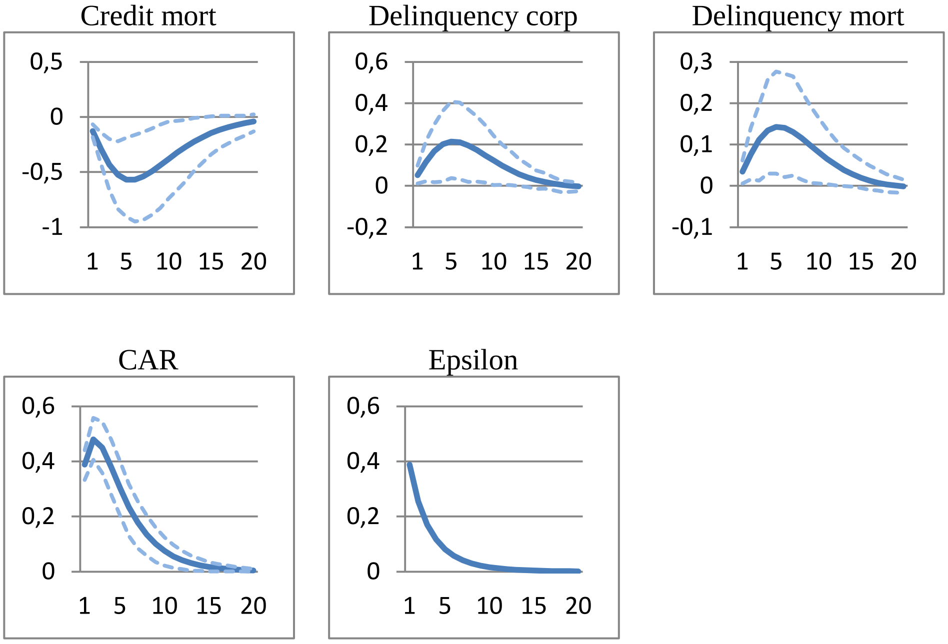
[32] Impulse response functions expressed in percentage deviations from the steady states to one standard deviation orthogonalized innovation to $u_t^{\varepsilon^i}$.

[33] Impulse response functions expressed in percentage deviations from the steady states to one standard deviation orthogonalized innovation to $u^{\varepsilon}_{CAR,t}$.

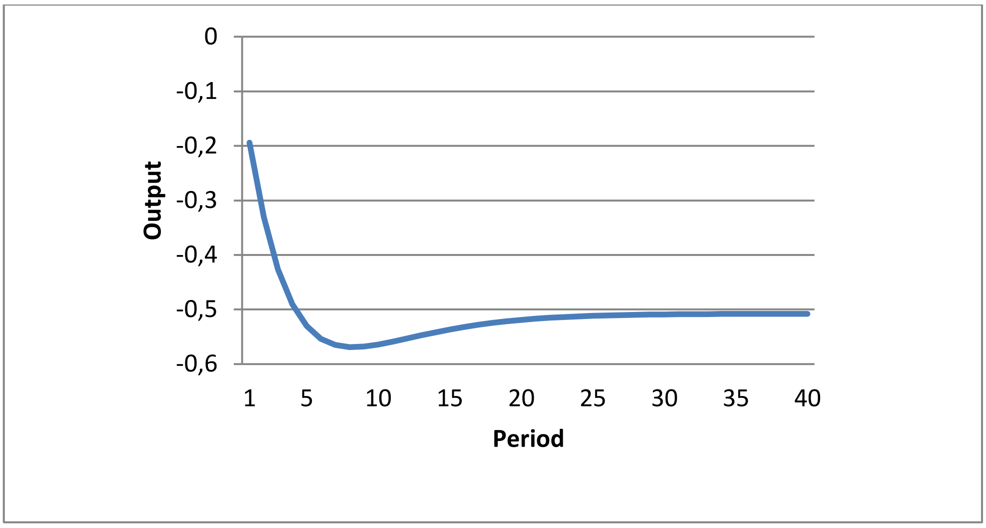


5.2 Macroeconomic Implications of a Permanent Shock

The impact of the policy shock also differs according to different degrees of persistence of the shock. The more persistent it is, the greater the impact it will have on the endogenous variables and the longer the system takes to return to its equilibrium. Since a persistent policy shock displaces the policy variable from its steady state and consequently displaces other variables from their respective steady state, I will in the following set the autoregressive coefficient in the equation for the capital adequacy ratio disturbance term equal to 0.99 (this coefficient was different for the temporary shock shown in figure 7), keeping all the remaining parameters set to the mode of posterior distributions. This is almost equivalent to a permanent increase of the capital adequacy ratio. Evaluating the response functions depicted in figure 8, following a close to "permanent shock" to the capital adequacy ratio equation, suggests that the estimated medium-term impact of raising the capital adequacy ratio by one per cent on GDP growth is in the interval of -0.50 and -0.55 percentage points below its steady-state level. It is also worth noting that an increase in the lending spread while reducing the level of output seems to leave its trend rate of growth unaffected. Despite the increase in lending spreads and the decrease in the supply of bank loans, following a permanent structural shock from the capital adequacy ratio disturbance term, the impact on growth will most likely be transitory; this line of reasoning is in line with the assumption made in the

MAG report. This is because when banks become less risky both the cost and quantity of credit should recover, reversing the impact on consumption and investment.

Figure.8 Response of Output to a permanent structural shock



6 The Countercyclical Capital Buffer of Basel III

This section analyzes the countercyclical capital buffer proposed by the new regulatory framework. The purpose of this section is to study the buffer using the macroeconomic framework developed above. As pointed out by Repullo and Saurina (2011) there are some issues related to the choice of a reference point to guide the building of the buffer. In particular it turns out that the BCBS proposal, aimed at trying to solve the pro-cyclicality problem of the entire regulation, might work in the opposite direction if the common reference point recommended, namely the credit-to-GDP gap, is uncritically chosen as the default reference point. A simple correlation analysis can show where the problem arises and Repullo and Saurina (2011) conduct such an exercise for a number of countries. Hence, I will first state the problem as highlighted in Repullo and Saurina (2011) then I will evaluate the issue using Norwegian data. Finally, I will analyze and evaluate the use of two different common reference points in the macroeconomic model.

The main rationale behind the use of a countercyclical capital buffer as noted by Repullo and Saurina (2011) is that "since capital is more expensive than retail deposits and other forms of funding, inducing banks to hold more capital during good times will help to moderate credit growth. The countercyclical buffer can be regarded as a supplementary instrument used by national authorities to mitigate the potential for the real economy to be affected by shocks that originate from within the financial sector itself. Thus, the regulatory authority will, using the deviation of the credit-to-GDP ratio as a common reference point, request banks to extend their capital conservation buffer, ranging from zero to 2.5 per cent of risk-weighted assets, in times of excessive credit growth.[34] In order to make the rule both predictable and reliable, national authorities will pre-announce the decision to raise the level of the buffer by up to 12 months ahead, while the decision to release the buffer will have an immediate effect (BCBS, 2010c). Whereas the use of the countercyclical capital buffer itself is appreciated, the use of a common reference point for making buffer decisions has come under greater scrutiny by Repullo and Saurina (2011). The first sub-section will review some of their main arguments succeeded by an investigation of the relevance of their findings for

[34] When the ratio of private credit accelerates well above its established trend for a sustained period, the likelihood of substantial credit losses and even a financial crisis increases (M Drehmann, C Borio, L Gambacorta, G Jimenez and C Trucharte, "Countercyclical capital buffers: exploring options", BIS Working Papers, no 317, July 2010).

Norway. In sub-section 6.2 I will analyze the effects on the model economy when the countercyclical capital buffer based on two different "common reference points" is taken into account. The equation used to evaluate the effects on the model economy closely captures the proposed methodology provided in the Basel III document (BCBS, 2010c).

6.1 Credit-to-GDP Gap as a Common Reference Point?

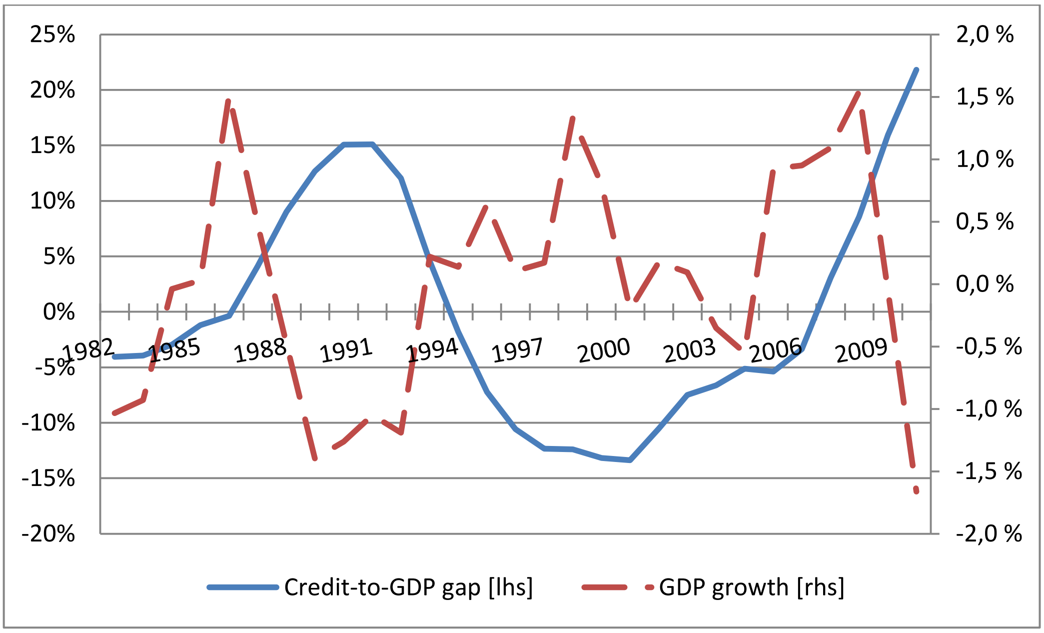
The use of a countercyclical capital buffer is a noteworthy macroprudential element of the Basel III framework. However, a recent paper by Repullo and Saurina (2011) shows that the key macroeconomic variable on which it is based, the deviation of the credit-to-GDP ratio with respect to its trend is negatively correlated with GDP growth for many countries.[35] The main findings from their study suggest that "the variable chosen by the Basel Committee as common reference point for taking buffer decisions may end up exacerbating the inherent pro-cyclicality of risk-sensitive bank capital."[36] They argue instead, based on a study conducted by Jordà et.al (2010), that the use of real credit growth as a leading indicator provides a better alternative for assessing systemic-wide-risk. Despite the fact that real credit growth lags the business cycle they provide data confirming a positive correlation between real credit growth and output growth for all the countries used in their sample.

In line with the findings of Repullo and Saurina (2011) I have in the following reproduced the case in question in order to explore the validity and relevance for Norway. Calculating the correlation between output growth and bank capital for the period 1982-2009 for Norway suggests that there is a small positive correlation of 0.0599. It should be noted that correlations are very sensitive to the choice of sample period. Thus, the slight positive correlation could plausibly be explained by the inclusion of the years Norway experienced a banking crisis. Computing the credit-to-GDP gap for the same period as above and then plotting this with the GDP growth rate gives us the graph below in figure 9. It is evident from the graph that the two variables in question are negatively correlated. This suggests that a mechanical application of a rule based on the credit-to-GDP gap would distort the main objective of Basel III because it signals to increase the countercyclical capital buffer when

[35] Correlations where computed for France, Germany, Italy, Japan, Spain and US showing an average correlation of -0.17 across countries.
[36] Using UK as an illustrative example they show that when GDP growth is low the credit-to-GDP gap tends to be high, and vice versa.

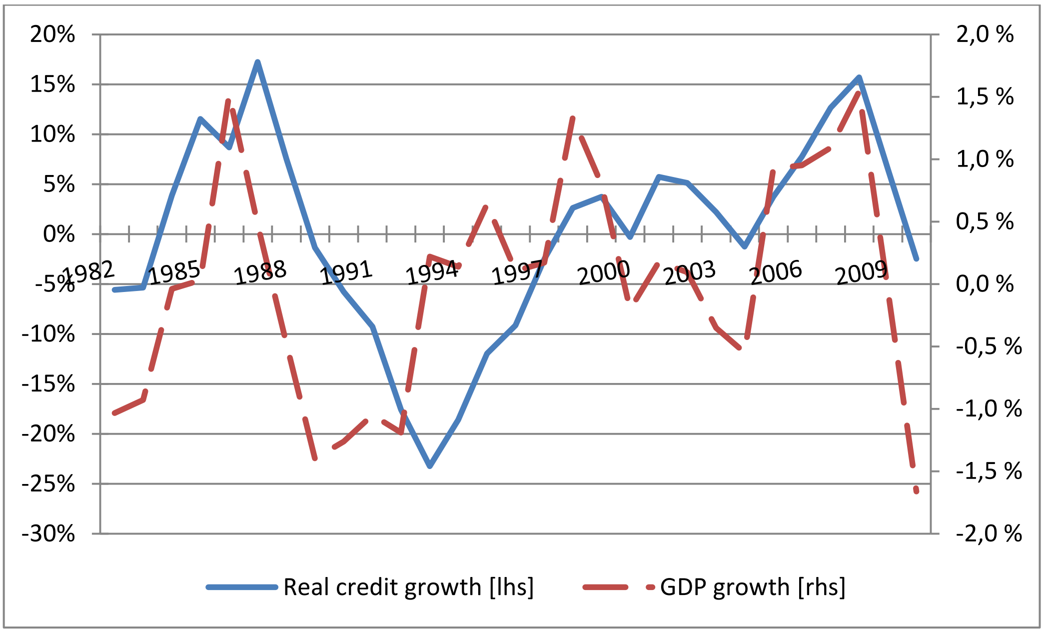
GDP growth is low and to reduce it when GDP growth is high. Computing the deviations of real credit growth with respect to a long-run average using a GDP-deflator for the sample period, and plotting this with output growth provides us the graph in figure 10. A closer look at figure 10 suggests that real credit growth follows the business cycle with a lag, but more closely than the credit-to-GDP gap. Calculating the correlation between the two variables demonstrate a positive correlation of 0.45. These findings suggest that an uncritical use of a common reference point can lead to results that are detrimental to the principal objective of the Basel III regulatory framework. Thus, the aim of the subsequent section is to investigate the properties of the model economy when a countercyclical capital buffer is included.

Figure.9 Credit-to-GDP gap and GDP growth, Norway, 1982-2010



Source: Norges Bank

Figure.10 Real credit growth and GDP growth, Norway, 1982-2010



Source: Norges Bank

6.2 The countercyclical capital buffer applied

The BCBS has in a guidance document for national authorities outlined a methodology for operating the countercyclical capital buffer with the objective as stated "to use a buffer of capital to achieve the broader macroprudential goal of protecting the banking sector from periods of excess aggregate credit growth that have been associated with the build-up of system-wide risk." In the same document they further stress that "Authorities in each jurisdiction are free to emphasize any other variables and qualitative information that make sense to them for purposes of assessing the sustainability of credit growth and the level of system-wide risk, as well as in taking and explaining buffer decisions. This includes constructing additional credit/GDP or other guides that are more closely aligned to the behavior of their financial systems" (BCBS, 2010c). The methodology provided in the annex of the guidance document has been conceptualized and further defined by Repullo and Saurina (2011) and can be summarized as follows:[37]

[37] The notations used are different from their paper so as not to contradict with previously used notations.

$$C_t = y_t - \overline{y_t}.$$

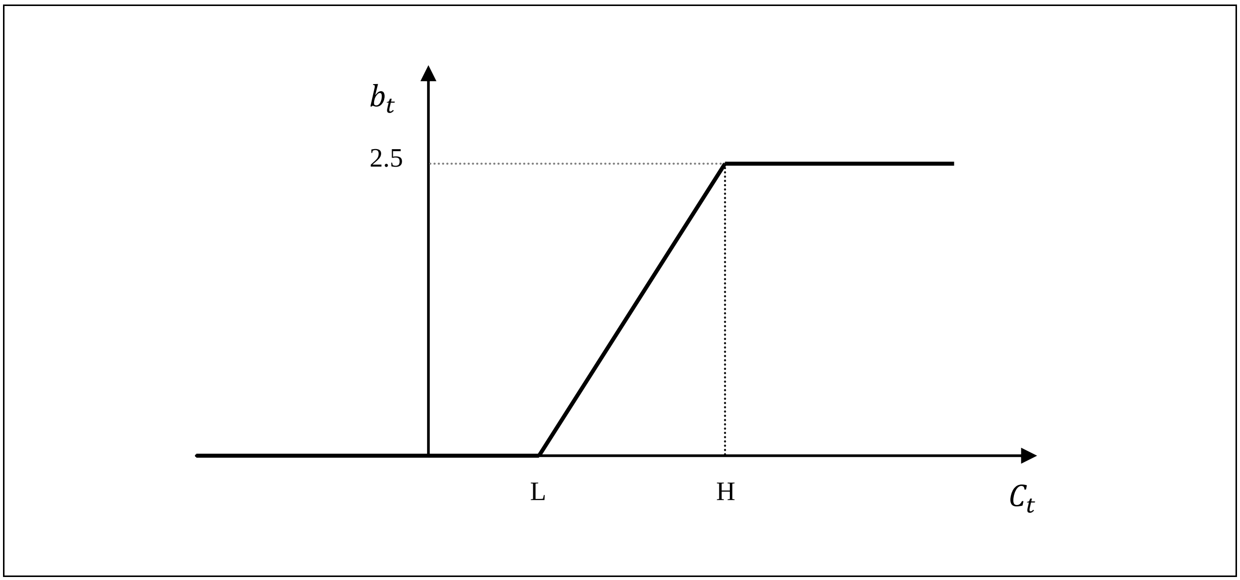
Where C_t is defined as the deviation of the aggregate private sector credit-to-GDP ratio from its trend. y_t describes the aggregate private sector credit-to-GDP ratio, while $\overline{y_t}$ denote the Hodrick-Prescott trend of y_t and is computed using a smoothing parameter λ = 400,000 (Repullo and Saurina, 2011).

With this in mind, the benchmark countercyclical capital buffer, b_t, are advised by the guidance document to be set according to the following rule:

$$b_t = b(C_t) = \begin{cases} 0 & if\ C_t < L \\ \dfrac{C_t - L}{H - L} 2.5 & if\ L \leq C_t \leq H. \\ 2.5 & if\ C_t > H \end{cases}$$

Where L and H denote a lower and upper bound for the gap (BCBS, 2010c).[38] The following graph illustrates the mechanical properties of the countercyclical buffer:

Figure.11 The relationship between the countercyclical capital buffer and the credit-to-GDP gap



[38] The BCBS guidance document has argued, based on their own analysis, that an “adjustment factor on L = 2 and H = 10 provides a reasonable and robust specification based on historical banking crisis” (BCBS, 2010c).

The methodology provided in the BCBS guidance document and rationalized by Repullo and Saurina (2011) is first and foremost a “rule” based approach to making buffer decisions. The methodology as such is not well-suited to be directly incorporated into the stylized DSGE model used in this paper. As a consequence, I have constructed two equations so as to make the countercyclical capital buffer a continuous approximation of the methodology outlined above. The equations provided capture in a suitable manner the properties of the methodology when used as a function of a common reference point, be it the credit-to-GDP gap or the real credit growth. These equations (when used separately as a rule in the capital adequacy ratio equation (14) in the banking sector block) alter the properties of the main model and generate some noteworthy results.

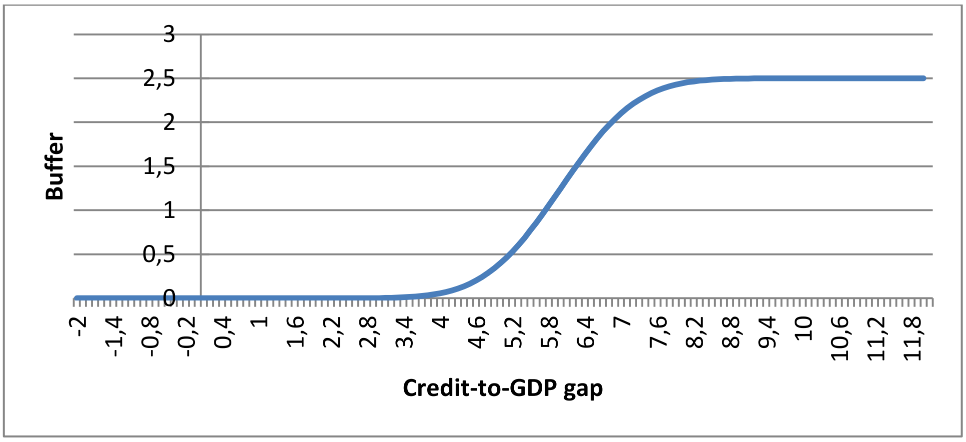
6.2.1 Equation for the Rule using Credit-to-GDP Gap

It turns out that the use of an equation specified as following seems to adequately capture the properties outlined in figure 11:

$$z_t = 2.5 * normcdf(\, m_t - 6) \tag{16}$$

Where z_t denote the buffer, while $normcdf$ represents a normal cumulative distribution function. The variable used for the credit-to-GDP gap m_t is defined in section 3. Using values for credit-to-GDP simulated from the estimated model with all the parameters set at the mode of their posterior distributions I obtain values for the buffer. These two quantities are plotted against each other in figure 12. The figure provided suggests that the equation bear a resemblance to the graph by Repullo and Saurina (2011) in figure 11.

Figure.12 Buffer response to Credit-to-GDP Gap



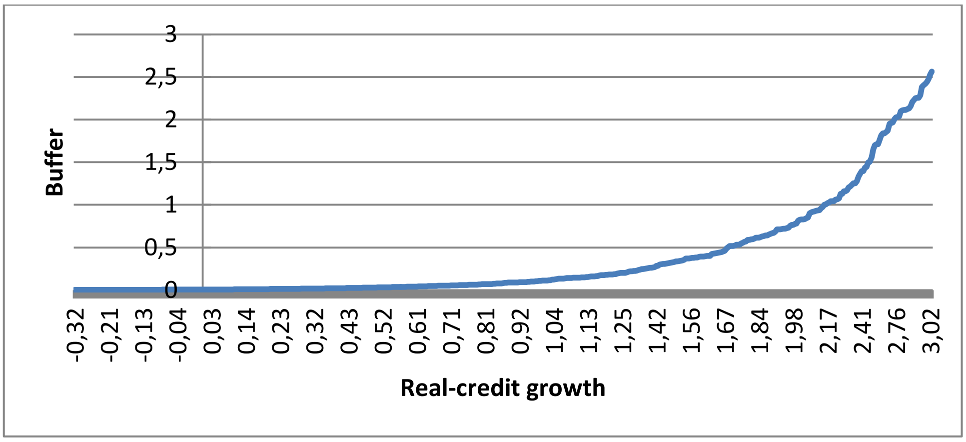
6.2.2 Equation for the Rule using Real Credit Growth

The following equation is defined in the similar way as the one above (i.e. with a normal cumulative distribution function), however with different number values and with the use of a real-credit growth as a common reference point instead.

$$z_t = 5 * normcdf(\, cr_{GROWTH,t} - 3) \tag{17}$$

Plugging in values for the real-credit growth from the estimated model simulated as explained above. The implied dynamics for the buffer is as in figure 13. According to our though the banking sector should start building up their capital buffer when the real-credit growth exceeds 0.5 per cent. After that limit they should keep increasing the buffer until the value of the buffer reaches its maximum level at 2.5. In the figure provided the buffer increases above this level, however, it is worth noting that the historical average for the real-credit growth has been around 2 per cent and the maximum growth was at 3.8 per cent.

Figure.13 Buffer Response to Real Credit Growth



6.3 The modified methodology applied and evaluated

The previous section provided two different rules to investigate the dynamic properties of the capital buffer. In this section I want to evaluate the result attained from a direct application of the two equations into the model economy.

The correlation between output growth and bank capital without a buffer in the model is 0.14. Using equation (16) in the estimated model seems to reduce the volatility of credit by reducing the standard deviation from 1.85 to 1.51. However it increases the volatility of output, increasing the standard deviation from a level of 1.16 to 1.48. Additionally, and more essentially, it alters the sign of the correlation between output growth and bank capital producing a strong negative correlation of -0.61. When using equation (17) instead, where the reference point for making buffer decisions is the real credit growth, I was, in addition to reducing both the volatility of credit growth and output growth, also able to increase the magnitude of the correlation between output growth and bank capital by generating a positive correlation of 0.22. These results are clearly supporting the use of real credit growth, partly because it dampens excessive fluctuations in both credit and output, but mainly, and more importantly, because it seems to produce results that are more aligned with the objectives of Basel III.

7 Concluding Remarks

In this paper I have studied the impact of higher capital requirements, which are both part and parcel of the newly proposed regulatory framework of Basel III, using an estimated semi-structural new Keynesian small open economy model for Norway. The proposed regulatory framework is assumed to make the financial system more robust and safer, though, not entirely without repercussions to the banking sector in particular and the real economy in general. Imposing banks to increase their capital to risk-weighted-assets ratio will, by raising funding costs, affect banking sector profitability. The regulatory framework is from the bank's viewpoint restricting asset expansion and from a broader viewpoint increasing the cost and reducing the quantity of credit. The paper has argued in line with the arguments found in the MAG report that the immediate response by the banking industry to higher capital requirements will be to increase their lending spreads (so as to keep their return on equity constant). The main component reducing aggregate demand and output in the model is higher lending spreads.

Despite the use of reduced-form equations, the model properties, when evaluated for model-fit (studying impulse responses following a monetary policy shock), seems to adequately capture structural features of the Norwegian economy. The main finding, studying the impulse response function, suggest that the effect of a one per cent increase of banks' capital requirement on output is negative, with a drop of 0.5 per cent at its peak reached after 4 quarters. Studying the same shock for credit in the model shows that credit responds by a small initial drop from baseline by -0.3 percentage point, followed by a continuing movement away from the original level in the subsequent quarters, reaching a trough in the sixth quarter at -1.54 percentage point before gradually progressing back to its initial steady-state. The effect of a permanent increase of one per cent in the capital adequacy ratio shows that GDP growth shifts by -0.50 to -0.55 percentage points below its initial steady-state level following a shock. The initial shock seems to displace the level of output, but the trend growth rate seems to be unaffected.

A second question highlighted in the introduction and addressed separately in this paper is the use of a countercyclical capital buffer to mitigate the inherent pro-cyclical feature of minimum capital requirement. Studying the model properties, both before and after the inclusion of a countercyclical capital buffer, clearly suggests that credit volatility is reduced, but not the volatility of output, when credit-to-GDP gap is used as a common reference point. It also creates a strong negative correlation of -0.61 between output growth and bank capital in the model. The use of real credit growth on the other hand shows some desirable properties. Next to reducing both the variance of credit and output (standard deviation of credit goes down from 1.85 to 1.71 and the standard deviation for output growth reduced from 1.16 to 1.13) it produces a positive correlation of 0.22 between output growth and bank capital. These results highlight that real credit growth used as an indicator and as a decision variable not only is more aligned with the core objectives of the new capital regulatory framework of Basel III but also with the behavior of the Norwegian financial system.

References

Adolfson, Malin, Stefan Laséen, Jesper Lindé and Mattias Villani (2007a) Bayesian estimation of an open economy DSGE model with incomplete pass–through, *Journal of International Economics*, vol. 72, pp. 481–511.

An, Sungbae, and Frank Schorfheide, "Bayesian Analysis of DSGE Models," *Econometric Reviews*, 26 (2007), 113–172.

Basel Committee on Banking Supervision (2009), "History of the Basel Committee and its Membership (August 2009), August, 2009.

Basel Committee on Banking Supervision (2009a), "Strengthening the resilience of the banking sector," Consultative Document, December, 2009.

Basel Committee on Banking Supervision (2010b): "Countercyclical Capital Buffer Proposal," Consultative Document, Bank for International Settlements, Basel.

Basel Committee on Banking Supervision (2010c): "Guidance for National Authorities Operating the Countercyclical Capital Buffer," Bank for International Settlements, Basel.

Bernanke, B.S. (1983), "Nonmonetary effects of the financial crisis in the propagation of the great depression," American Economic Review 73:257-276.

Bernanke, Ben, Mark Gertler, and Simon Gilchrist, 1999, "The Financial Accelerator in a Quantitative Business Cycle Framework," *Handbook of Macroeconomics*, John Taylor and Michael Woodford editors.

Brubakk, Leif, Tore Anders Husebo, Junior Maih, Kjetil Olsen, and Magne Ostnor. 2006. "Finding NEMO: Documentation of the Norwegian Economy Model." Norges Bank Staff Memo 2006/6.

Brunnermeier, Markus, 2009. "Deciphering the Liquidity and Credit Crunch 2007-2008," *Journal of Economic Literature*: 77-100.

Calvo, Guillermo (1983). Staggered prices in a utility maximizing framework, *Journal of Monetary Economics*, vol. 12, pp. 383–398.

Canova, F (2007). *Methods for Applied Macroeconomic Research*. Princeton University Press.

Caruana, J. (2010): Basel III: Towards a Safer Financial System, Speech at the 3rd Santander International Banking Conference, Madrid.

Clarida, Richard, Jordi Galí and Mark Gertler (1999): "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature* 37, 1661-1707.

Disyatat, P. (2010): "The bank lending channel revisited", BIS Working Paper No 297, February.

Drehmann M., Borio C., Gambacorta L., Jimenez G. & Trucharte C. (2010): "Countercyclical capital buffers: Exploring Options," BIS Working Paper, 317.

Fisher, I. (1933): "The debt-deflation theory of great depressions", Econometrica 1:337-357.

Freixas, X., and J.-C. Rochet, 2008, *Microeconomics of Banking*. Cambridge, MA: MIT Press.

Gelain, P. and D. Kulikov (2009): An Estimated Dynamic Stochastic General Equilibrium Model with Financial Frictions for Estonia, Bank of Estonia.

Gertler, M., and N. Kiyotaki (2010): Financial Intermediation and Credit Policy in Business Cycle Analysis, *Handbook of Monetary Economics*.

Institute of International Finance (2010). *The Net Cumulative Economic Impact of Banking Sector Regulation: Some New Perspectives*, October 2010.

Jacobsen, Dag Henning., Kloster, Thea Birkeland., Kvinlog, Aslak Bakke., and Larsen, Unni. (2011): "Makroøkonomiske virkninger av høyere kapitalkrav for bankene" Staff Memo 14/2011, Norges Bank.

Jordà, O., M. Schularick, and A. M. Taylor (2010): "Financial Crises, Credit Booms, and External Imbalances: 140 Years of Lessons," *NBER Working Paper*, no 16567.

Macroeconomic-Assessment-Group (2010a): *Assessing the Macroeconomic Impact of the Transition to Stronger Capital and Liquidity Requirements*. Interim Report, Bank for International Settlements, Basel.

- (2010b): *Assessing the Macroeconomic Impact of the Transition to Stronger Capital and Liquidity Requirements*. Final Report, Bank for International Settlements, Basel.

NOU (2011): "Bedre rustet mot finanskriser. Finanskriseutvalgets utredning" NOU 2011:1.

Peñaloza, Sámano Daniel (2011): "In the quest of macroprudential policy tools," *MPRA Paper*, no 30738, University Library of Munich, Germany.

Reinhart, Carmen M., and Kenneth Rogoff, 2009, *This Time is Different: Eight Centuries of Financial Folly*, Princeton: Princeton University Press.

Repullo, R and J Saurina (2011): "The countercyclical capital buffer of Basel III: A critical assessment," *CEPR Discussion Papers*, no 8304.

Rotemberg, Julio and Michael Woodford (1999): "Interest Rate Rules in an Estimated Sticky Price Model," in J.B. Taylor ed., *Monetary Policy Rules*, University of Chicago Press.

Santos, J.A.C. (2001b) "Bank Capital Regulation in Contemporary Banking Theory: A Review of the Literature," Financial Markets, Institutions and Instruments 10(2), 41-8.

Schorfheide, F. (2010): "Estimation and Evaluation of DSGE Models: Progress and Challenges," *NBER Working Paper*.

Sidaoui, J., and M. Ramos-Francia (2008): The Monetary Transmission Mechanism in Mexico: Recent Developments, *BIS Papers chapters*, 35, 363.394.

Slovik, P. and B. Cournède (2011): “Macroeconomic Impact of Basel III”, *OECD Economics Department Working Paper No*. 844, Paris, France: OECD.

Smets, F., and R. Wouters (2003b): “An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area”, *Journal of the European Economic Association* 1(5), 1123.1175.

Walsh, Carl E. 2010. *Monetary Theory and Policy*. Massachusetts: MIT Press.

Woodford, M. (2003): *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton University Press

Appendix

Table 1: The prior and posterior distributions of the Norwegian DSGE model parameters

Parameter	Prior distribution			Posterior distribution			
Std of shocks; Norway	type	mean	Std. deviation	mean	Std. deviation	10%	90%
σ_{u^D}	*I.G*	0.20	∞	0.1616	0.0169	0.1334	0.1893
σ_{u^v}	*I.G*	0.20	∞	0.4574	0.0573	0.3601	0.5533
σ_{u^ω}	*I.G*	0.20	∞	1.1072	0.1193	0.8627	1.3339
$\sigma_{u^{\varepsilon^i}}$	*I.G*	0.20	∞	0.2420	0.0242	0.2034	0.2780
$\sigma_{u^{\varepsilon^{spread^{corp}}}}$	*I.G*	0.20	∞	0.2425	0.0241	0.2048	0.2781
$\sigma_{u^{\varepsilon^{spread^{mort}}}}$	*I.G*	0.20	∞	0.2438	0.0245	0.2066	0.2801
$\sigma_{u^{\varepsilon^{cr^{corp}}}}$	*I.G*	0.20	∞	2.3605	0.2119	2.0199	2.7045
$\sigma_{u^{\varepsilon^{cr^{mort}}}}$	*I.G*	0.20	∞	1.3902	0.1245	1.1876	1.5884
$\sigma_{u^{\varepsilon^{cr^{tot}}}}$	*I.G*	0.20	∞	0.4247	0.040	0.3621	0.4846
$\sigma_{u^{\varepsilon^{CAR}}}$	*I.G*	0.20	∞	0.3887	0.0348	0.3330	0.4430
$\sigma_{u^{\varepsilon^{\pi}}}$	*I.G*	0.20	∞	0.6076	0.0579	0.5177	0.6967
$\sigma_{u^{\varepsilon^{delin}}}$	*I.G*	0.20	∞	0.5368	0.0633	0.4532	0.6169
$\sigma_{u^{\varepsilon^{delin^{corp}}}}$	*I.G*	0.20	∞	0.9004	0.0870	0.7671	1.0405
$\sigma_{u^{\varepsilon^{delin^{mort}}}}$	*I.G*	0.20	∞	0.1862	0.1828	0.0459	0.3516
Std of shocks; Foreign							
$\sigma_{u^{u^f}}$	*I.G*	0.20	∞	0.5162	0.0437	0.4436	0.5888
σ_{u^1}	*I.G*	0.20	∞	0.2236	0.0193	0.1934	0.2531
σ_{u^2}	*I.G*	0.20	∞	0.2285	0.0204	0.1952	0.2596
σ_{u^3}	*I.G*	0.20	∞	0.1377	0.0169	0.1122	0.1614

Table 2: The prior and posterior distributions of the Norwegian DSGE model parameters

Parameter	Prior distribution			Posterior distribution			
AR coeff; Norway	type	mean	Std. deviation	mean	Std. deviation	10%	90%
ρ_π	*Beta*	0.50	0.10	0.130	0.0379	0.0735	0.1836
ρ_x	*Beta*	0.50	0.10	0.7647	0.0640	0.6654	0.8655
ρ_r	*Beta*	0.50	0.10	0.7107	0.0433	0.5820	0.8383
ρ_{ε^π}	*Beta*	0.50	0.10	0.1243	0.0465	0.0711	0.1778
ρ_{ε^x}	*Beta*	0.50	0.10	0.7575	0.0646	0.6618	0.8601
ρ_{ε^r}	*Beta*	0.50	0.10	0.6893	0.0595	0.5498	0.8318
ρ_f	*Beta*	0.50	0.10	0.2879	0.0579	0.1707	0.3991
ρ_v	*Beta*	0.50	0.10	0.4498	0.0458	0.3204	0.5708
ρ_u	*Beta*	0.50	0.10	0.5043	0.0563	0.3728	0.6303
ρ_ω	*Beta*	0.50	0.10	0.4217	0.0722	0.2862	0.5586
ρ_{ε^i}	*Beta*	0.50	0.10	0.3372	0.0676	0.2221	0.4464
ρ_{u^f}	*Beta*	0.50	0.10	0.2722	0.0454	0.1645	0.3720
$\rho_{\varepsilon_{spread^{corp}}}$	*Beta*	0.50	0.10	0.6894	0.0662	0.5852	0.7957
$\rho_{\varepsilon_{spread^{mort}}}$	*Beta*	0.50	0.10	0.6417	0.0573	0.5344	0.7486
$\rho_{\varepsilon_{cr^{corp}}}$	*Beta*	0.50	0.10	0.6490	0.0679	0.4624	0.8349
$\rho_{\varepsilon_{cr^{mort}}}$	*Beta*	0.50	0.10	0.7486	0.1198	0.5982	0.9035
$\rho_{\varepsilon_{cr}}$	*Beta*	0.50	0.10	0.2992	0.0678	0.1851	0.4088
$\rho_{\varepsilon_{CAR}}$	*Beta*	0.50	0.10	0.6477	0.0488	0.4751	0.8102
ρ_{ε_π}	*Beta*	0.50	0.10	0.2846	0.0687	0.1777	0.3909
$\rho_{\varepsilon_{delin}}$	*Beta*	0.50	0.10	0.6983	0.0504	0.5788	0.8244
$\rho_{\varepsilon_{delin^{corp}}}$	*Beta*	0.50	0.10	0.5642	0.0521	0.4117	0.7091
$\rho_{cr_{tot}}$	*Beta*	0.50	0.10	0.5116	0.0852	0.3617	0.6652

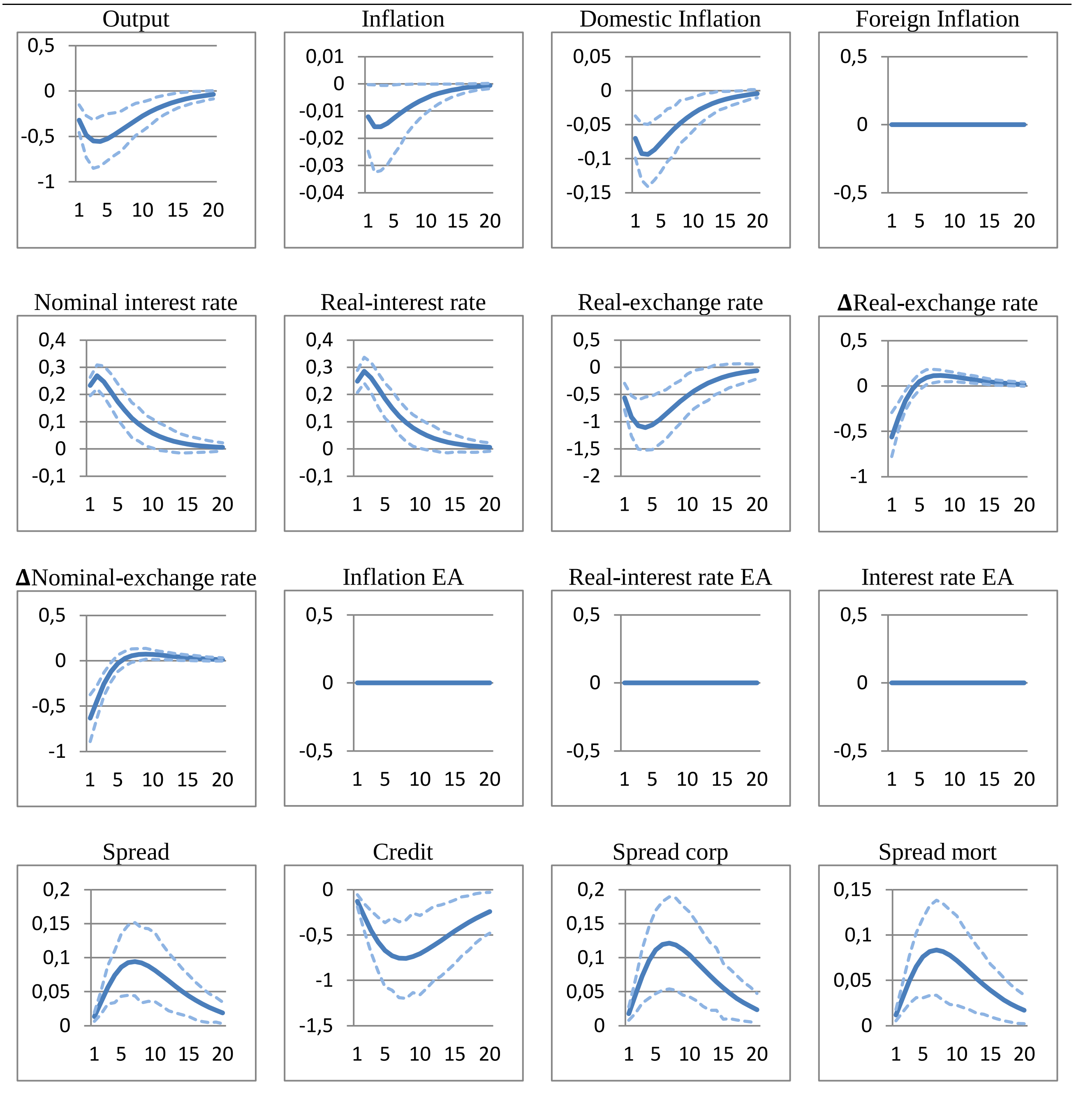
Table 3: The prior and posterior distributions of the Norwegian DSGE model parameters

Parameter	Prior distribution			Posterior distribution			
Core model parameters	type	mean	Std. deviation	mean	Std. deviation	10%	90%
a_1	*Normal*	0.41	0.05	0.2760	0.0286	0.2051	0.3483
a_2	*Normal*	0.58	0.05	0.4509	0.0316	0.3763	0.5286
a_3	*Normal*	0.05	0.005	0.0411	0.0025	0.0331	0.0488
a_4	*Normal*	0.03	0.005	0.0233	0.0028	0.0162	0.0305
b_1	*Normal*	0.41	0.05	0.3406	0.0562	0.2832	0.40
b_2	*Normal*	0.58	0.05	0.5179	0.0401	0.4550	0.5834
b_3	*Normal*	0.20	0.05	0.1815	0.0492	0.1079	0.2558
b_4	*Normal*	0.03	0.05	0.1508	0.0069	0.1336	0.1688
b_5	*Normal*	0.03	0.005	0.0334	0.0289	0.0128	0.0543
b_6	*Normal*	0.016	0.005	0.1863	0.2267	0.0308	0.3305
c_1	*Normal*	0.50	0.05	0.4552	0.0214	0.4011	0.5113
c_2	*Normal*	0.50	0.05	0.4755	0.0458	0.4225	0.538
d_1	*Normal*	0.50	0.05	0.4755	0.0415	0.3880	0.5583
d_2	*Normal*	0.125	0.01	0.1270	0.0086	0.1119	0.1426
d_3	*Beta*	0.50	0.10	0.8622	0.0262	0.8187	0.9060
Identities; Norway							
w_1	*Uniform*	0	1	0.1697	0.1359	0.0034	0.3348
w_2	*Uniform*	0	1	0.1118	0.0738	0.0028	0.2174
τ^{corp}	*Uniform*	0	1	0.2918	0.0356	0.2378	0.3474

Table 4: The prior and posterior distributions of the Norwegian DSGE model parameters

Parameter *Banking block parameters*	Prior distribution type	Prior mean	Prior Std. deviation	Posterior mean	Posterior Std. deviation	10%	90%
γ_1^{corp}	*Beta*	0.50	0.10	0.3730	0.0626	0.2428	0.4981
γ_3^{corp}	*Normal*	0.02	0.005	0.3277	0.0657	0.2391	0.4217
γ_1^{mort}	*Beta*	0.50	0.10	0.3869	0.1205	0.2675	0.5095
γ_3^{mort}	*Normal*	0.02	0.005	0.2756	0.0374	0.1924	0.3627
μ_1^{corp}	*Beta*	0.50	0.10	0.7751	0.0646	0.6518	0.9030
μ_2^{corp}	*Normal*	0.14	0.001	0.6809	0.0703	0.523	0.8362
μ_3^{corp}	*Normal*	0.08	0.005	0.3091	0.070	0.1870	0.4334
μ_1^{mort}	*Beta*	0.50	0.10	0.6704	0.0768	0.4985	0.8505
μ_2^{mort}	*Normal*	0.014	0.001	0.7201	0.067	0.5577	0.8796
μ_3^{mort}	*Normal*	0.08	0.005	0.3945	0.0539	0.2751	0.5181
α_1	*Beta*	0.50	0.10	0.5875	0.0571	0.4162	0.7680
γ_2^{corp}	*Normal*	0.05	0.008	0.1232	0.0101	0.1077	0.1386
γ_2^{mort}	*Normal*	0.05	0.008	0.1476	0.0083	0.1324	0.1633
π_1^{corp}	*Beta*	0.50	0.10	0.6712	0.0558	0.5624	0.7758
π_2^{corp}	*Normal*	0.05	0.008	0.4499	0.0760	0.3230	0.5810
π_1^{mort}	*Beta*	0.50	0.10	0.6706	0.050	0.5484	0.7876
π_2^{mort}	*Normal*	0.05	0.008	0.3016	0.1101	0.1985	0.4016

Figure 14: Impulse Response Functions Results[39] (Monetary policy shock)



[39] Impulse response functions expressed in percentage deviations from the steady states to one standard deviation orthogonalized innovation to $u_t^{\varepsilon i}$.

Figure 15: Impulse Response Functions Results (Monetary policy shock)

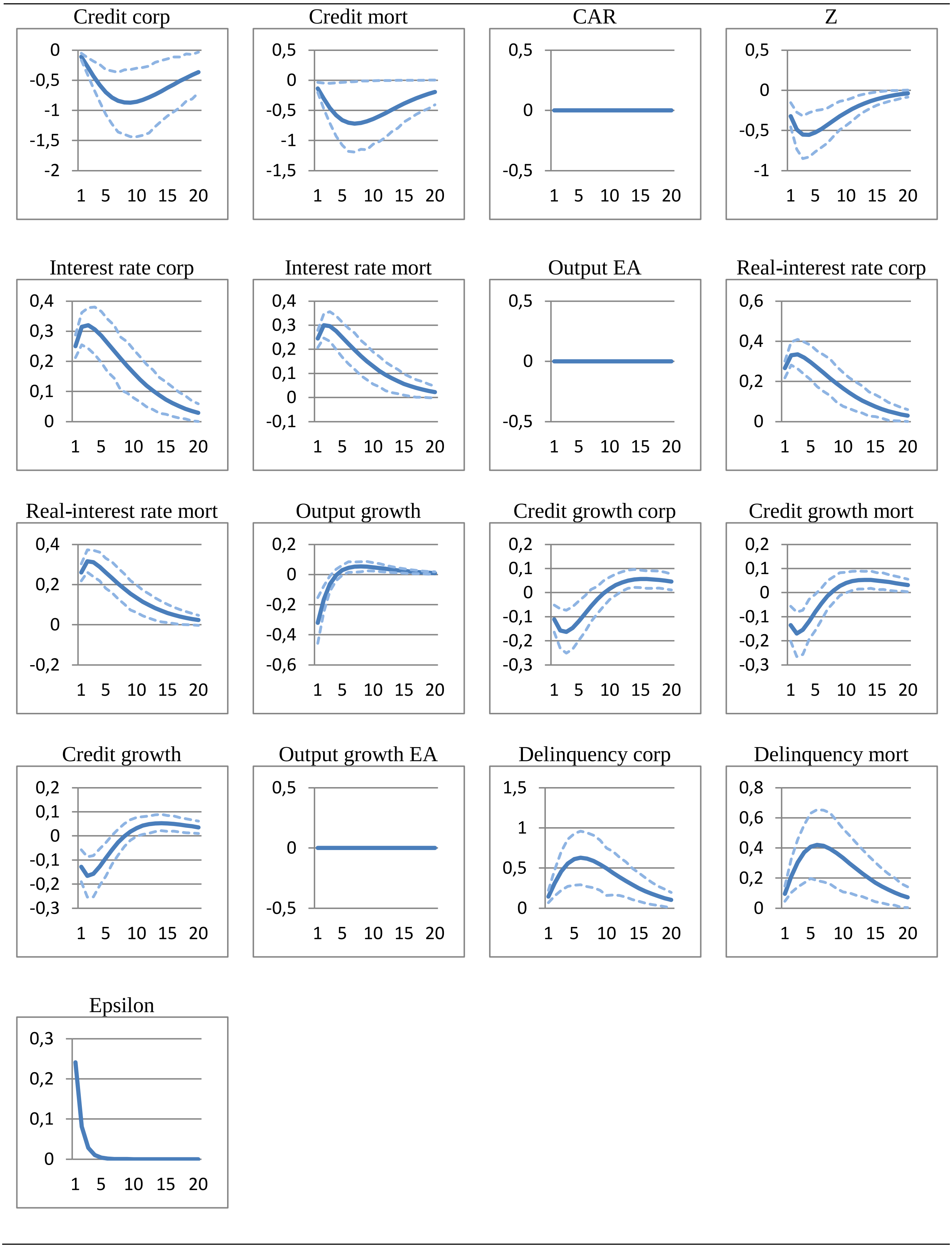
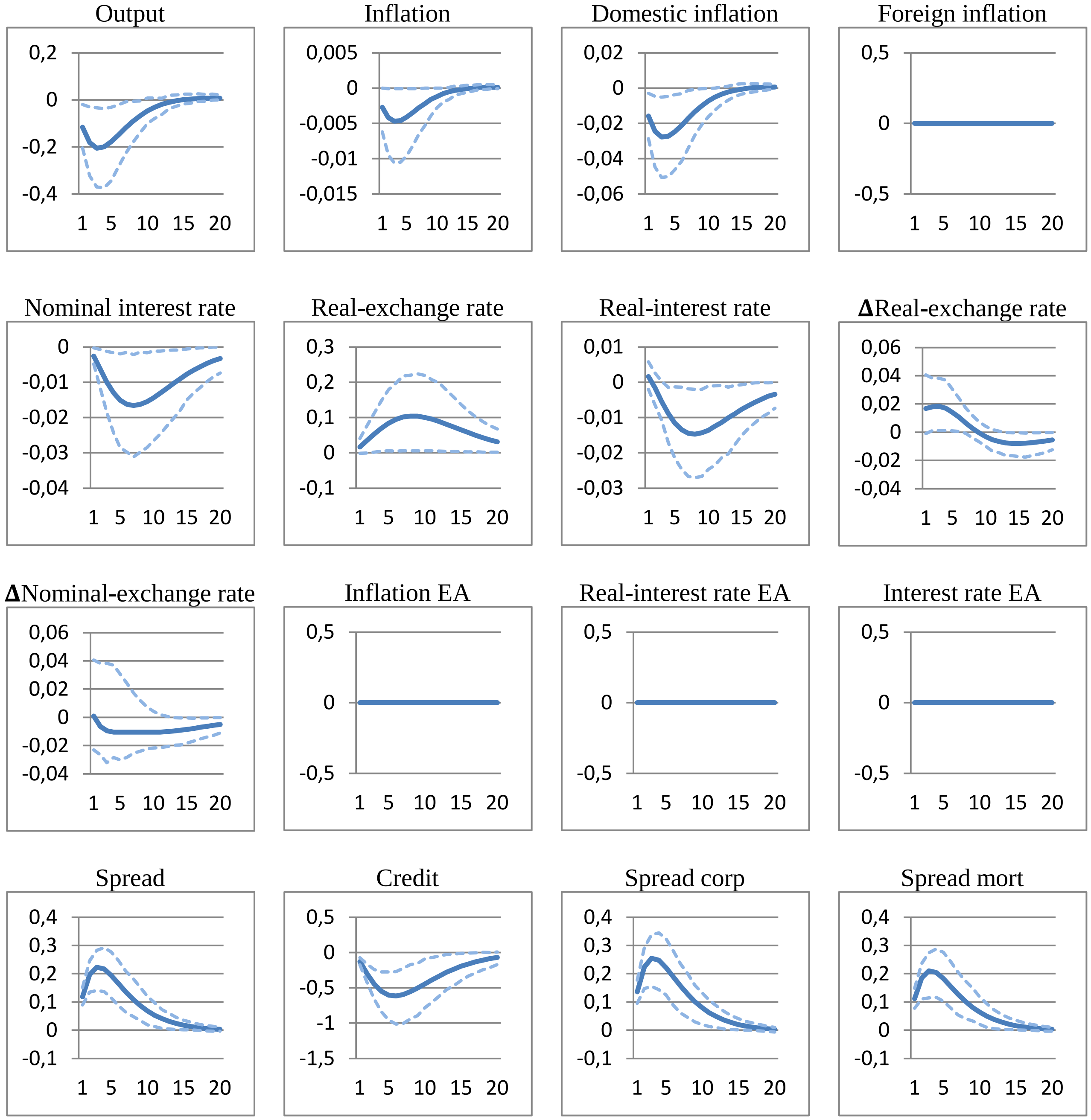


Figure 16: Impulse Response Functions Results (CAR shock)[40]



[40] Impulse response functions expressed in percentage deviations from the steady states to one standard deviation orthogonalized innovation to $u^{\varepsilon}_{CAR,t}$.

Figure 17: Impulse Response Functions Results (CAR shock)